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PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

IN THIS ISSUE: McHugh — *Distribution of Black-footed Albatross* • Matthews — *Feeding Habits of Sand Crab* • Womersley — *New Australian Marine Algae* • Randall — *Revision of Surgeon Fish* — Zebrasoma *and* Paracanthurus • Bowman — *New Copepod from Northeastern Pacific* • Dell — *Land Mollusca of Treasury Islands* • Webb — *Phytochemical Survey of Papua-New Guinea* • Gosline — *Fish Fauna of Johnston Island* • News Notes • Index

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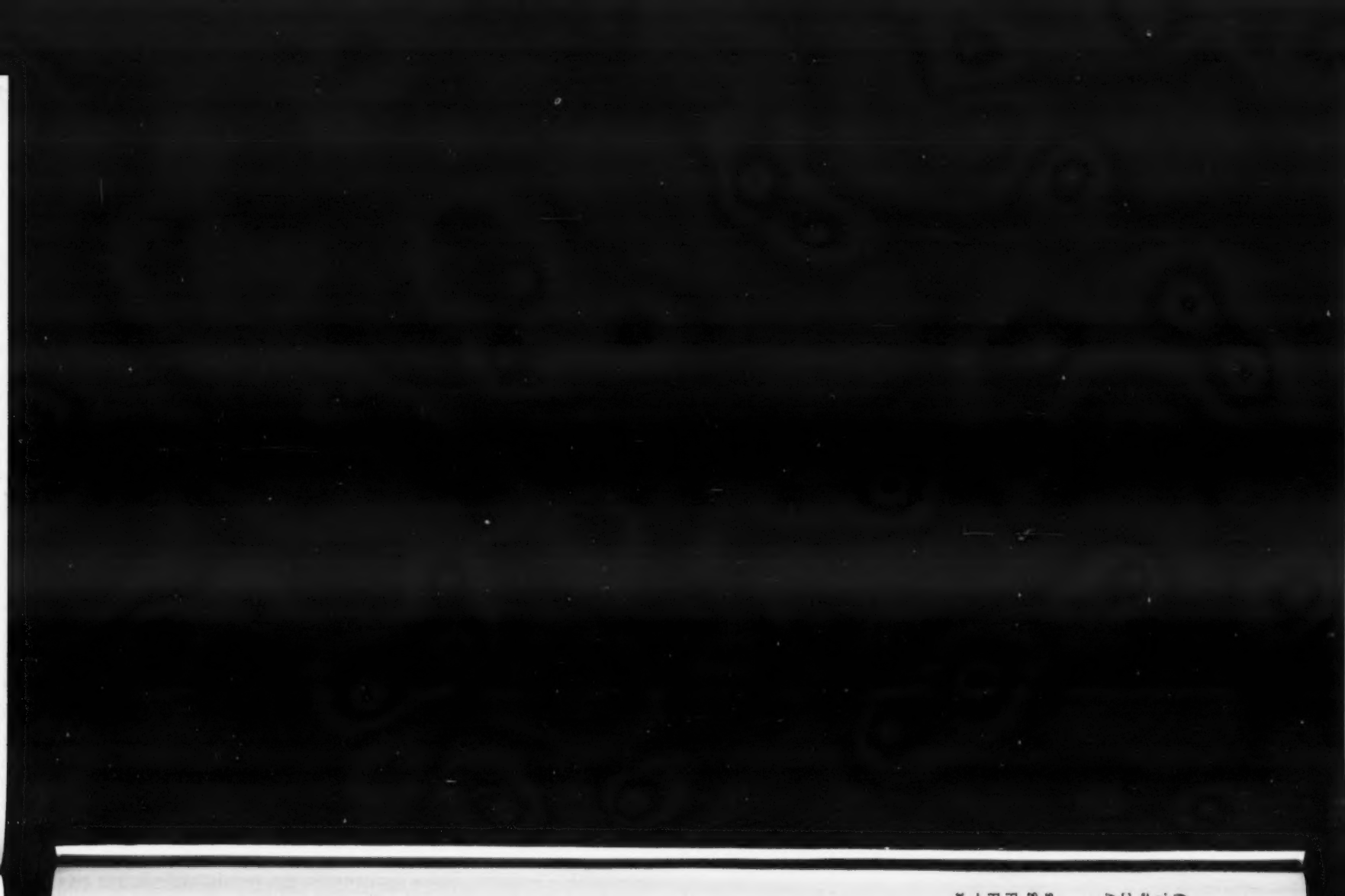
PREPARATION OF MANUSCRIPT

Although no manuscript will be rejected merely because it does not conform to the style of PACIFIC SCIENCE, it is suggested that authors follow the style recommended herein and exemplified in the journal.

(Continued on inside back cover)



PACIFIC SCIENCE

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Distribution of Black-footed Albatross, *Diomedea nigripes*, off the West Coast of North America, 1949 and 1950[1]

J. L. McHugh[2]

Since the oceanographic surveys of the California Cooperative Sardine Research Program began in March 1949, records have been kept of the numbers of albatrosses seen at each station. At monthly intervals the ships have covered an area approximately 1,300 miles long by 400 miles wide. The patterns of stations occupied, differing somewhat from cruise to cruise, and altered considerably in 1950, have been figured by McHugh (1950), Anonymous (1950), and McHugh and Ahlstrom (1951).

These albatross observations have formed a part of the objective, conceived early in the development of the research program, to study as many phases of the biology of the region as possible. Felin and Marr (1951) already have pointed out the importance of these subsidiary investigations in relation to the main purpose of the sardine program.

INDICES OF ABUNDANCE

Usually, counts were made shortly after the ship hove to at each station, and again just before departure. The second count commonly, but not always, exceeded the first (McHugh, 1950). The indices of abundance used here are based on the maximum numbers of birds observed at each station. For obvious reasons, no record was made at stations occupied during darkness, although albatrosses sometimes were seen at night (McHugh, 1952).

It is believed that several factors other than relative abundance may influence the counts. Birds may follow a ship as it cruises between stations, but it is not believed that the Black-footed Albatross travels great distances in this way (Miller, 1942; Thompson, 1951). The tendency to congregate about the motionless vessel may vary with weather conditions, especially if the frequency and duration of soaring flight is related to wind force, although an attempt to analyse the data along these lines produced no clear-cut relationship. Furthermore, counts may tend to increase during the day (McHugh, 1950) or when the ship is in an area for longer periods (Yocom, 1947). The visual acuity of birds and observers is affected almost certainly by atmospheric conditions and wind. The many observers undoubtedly varied in interest and in acuteness of vision. For these reasons, counts at adjacent stations were averaged by dividing the survey area into 21 blocks, by a grid of three blocks east to west and seven north to south (Fig. 1). These blocks are not equal in area, for the species seldom approaches within sight of shore, and often is not present in great numbers at the inshore stations. To avoid masking the reduced abundance near shore, the seven inshore blocks were chosen as far as possible to in-

[1] Contributions from the Scripps Institution of Oceanography, New Series, No. 805. Manuscript received February 10, 1955.

[2] Director, Virginia Fisheries Laboratory, Gloucester Point, Virginia.

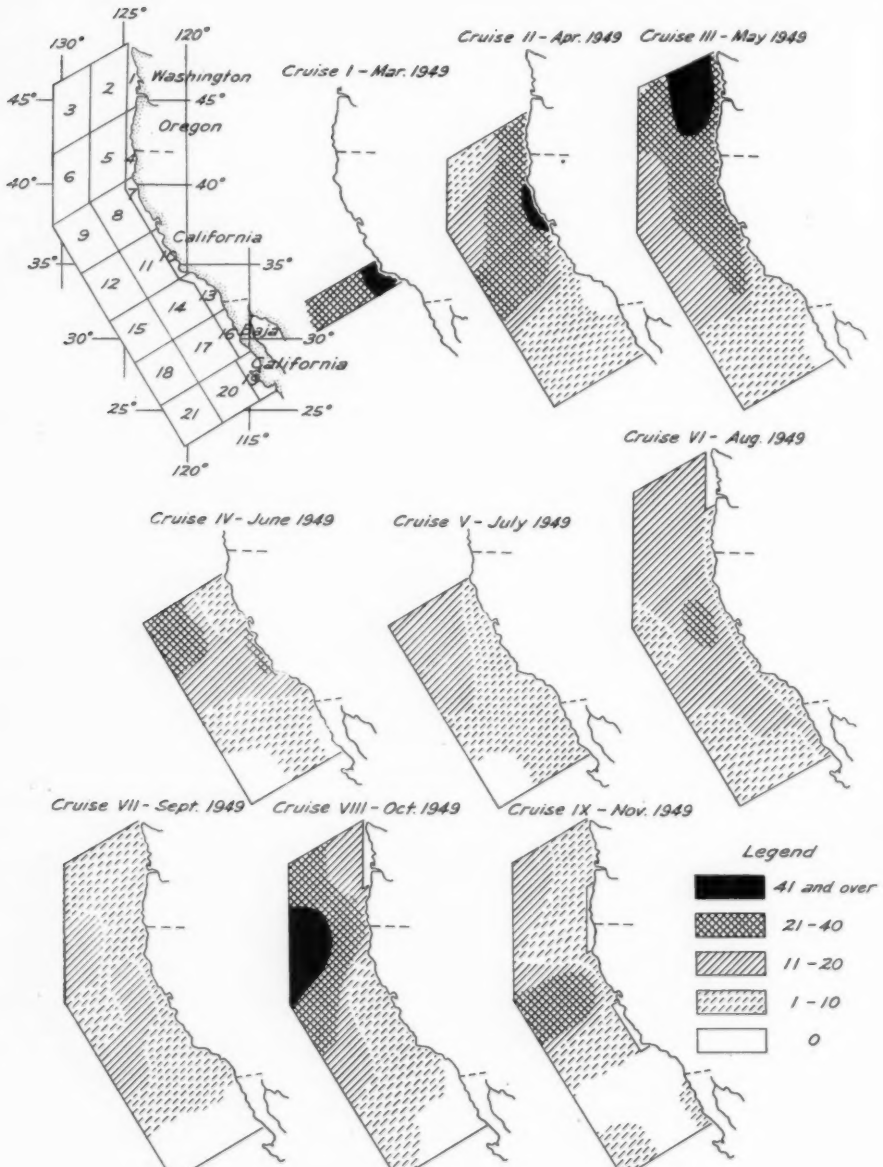

FIG. 1. Locations and numbers of blocks from which indices of albatross abundance were derived in 1949 and 1950 (upper left), and distribution of Black-footed Albatrosses over the survey area during 1949. The contours were drawn according to the average numbers of birds per station in each block.

clude only the inshore stations on each line. Their offshore limit is a line running roughly parallel to the coast about 40 nautical miles westward of the major promontories. The second series of blocks extends from the western boundary of the first and has a width of about 160 miles east to west; the third is approximately equal in width to the second. Each of the seven inshore blocks, about 9,600 square nautical miles, is roughly one-quarter the average area of the remainder. The inshore blocks each contained two stations in 1949, and an average of six in 1950; each offshore block contained an average of nine stations in each year.

As a monthly index of abundance, all counts within each block were averaged, a process designed to minimize many of the most serious sources of error. These indices may be defined as representing the best available estimate of relative monthly abundance within each block. There is little point in expanding these estimates into a measure of the total number of birds present in the area, for there is no adequate basis for determining the absolute density of birds per unit area that each count represents. Assuming, however, that all birds within a ten-mile square collect around the ship while it occupies a station, the total number of Black-footed Albatrosses present within the region surveyed in May 1949, the month in which most birds were observed, was close to 100,000. This estimate is not inconsistent with the results of the census made by Fisher (1949) on the Island of Midway.

The cruises have not always covered the entire region included within the station pattern. Sometimes parts of the area have been missed on account of adverse weather conditions or mechanical breakdowns. Sometimes the station coverage has been shifted according to plan, in response to seasonal changes in the location of sardine spawning. Blocks 7 to 18 inclusive were occupied on most cruises in 1949 and 1950, and it is possible to calculate an index of abundance for the waters off the California coast by summing the indices for these blocks (Table 1). However, it would be advantageous to discover a more restricted area that would reflect the abundance of birds equally well. Block 11 was chosen because it is sufficiently far north to contain relatively large numbers of albatrosses, yet close enough to an important sardine spawning area that it may be expected to be traversed on most, if not all, cruises. A high and statistically significant coefficient of correlation was obtained between the monthly indices for block 11 and for the larger area exclusive of block 11 ($r = +0.863$, P much less than 0.01). In view of the many possible sources of error to which these indices are subject, it is concluded that the relative abundance of birds in block 11, lying west of Point Conception, is indicative of the relative abundance off the entire California coast.

TABLE 1

INDICES OF ABUNDANCE OF BLACK-FOOTED ALBATROSSES IN THE REGION COVERED BY BLOCKS 7 TO 18 INCLUSIVE

MONTHS	INDICES OF ABUNDANCE	
	1949	1950
February	...	63
March	...	113
April	132	66
May	106	74
June	86	87
July	60	62
August	78	61
September	46	25
October	66	...
November	59	...

GENERAL DISTRIBUTION

Thompson (1951) has observed *Diomedea nigripes* as far south as 15° 40′ N. in the Central Pacific. Along the west coast of North America, however, the species has never been observed in great abundance south of Cedros Island, off the coast of Baja California. Al-

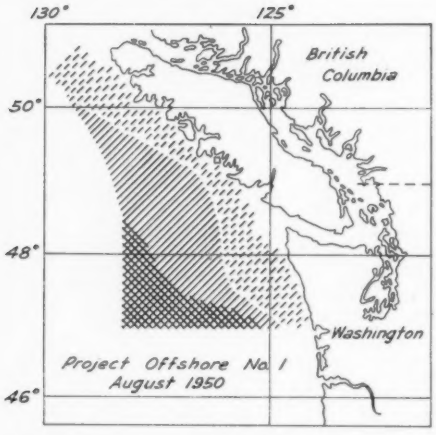

FIG. 2. Distribution of Black-footed Albatrosses off the British Columbia and Washington coasts in August 1950. Legend as in Figs. 1 and 3. The contours were drawn according to the numbers of birds at each station.

though Cruise 20, in November 1950, extended the coverage southward almost to 20° N., no albatrosses were seen at this time off the entire Baja California coast. Later cruises, reaching this latitude in all seasons, may be expected to define more accurately the southern extent of the species range.

To the northward, the Black-footed Albatross is common off British Columbia and Alaska, and has been seen irregularly in the Bering Sea (Kenyon, 1950). Counts supplied through the cooperation of Dr. J. L. Hart and R. J. Waldie from off the coasts of Washington and British Columbia in August 1950 range from 1 to 24, and average 13 birds per station (Fig. 2).

To the westward, in 1949 and 1950 only one cruise extended more than about 400 miles offshore. On this cruise, numbered 18, in September 1950, the maximum count in the region outside the grid defined in Figure 1 was six birds at station 70.220. *Diomedea nigripes* is found across the entire Pacific, however, for it breeds in the mid-Pacific islands in winter and spreads over the north Pacific at other seasons.

SEASONAL DISTRIBUTION AND ABUNDANCE

In 1949 and 1950 Black-footed Albatrosses were about twice as abundant in the survey area over the period March to May as in any other month. The distribution of counts in 1949 (Fig. 1) suggests that the decrease in abundance in the summer months is caused by a general northerly migration, for the greatest density of birds was encountered off Point Conception in March, off San Francisco in April, and off the Columbia River in May, an average northward shift of about 300 nautical miles per month. Not until October did similar concentrations appear again within the survey area, this time in a region well offshore from Cape Mendocino. In 1949 also, there appeared to be a general shift of the population from inshore in spring to offshore in fall.

In 1950 (Fig. 3) there were less definite indications of a progressive northerly migration, although the index of abundance was highest in March. If a northward movement did take place, it probably occurred earlier than in 1949, and there is some evidence that the return movement began in May, for the birds were more abundant off Cape Blanco in May, and off San Francisco in June than at any other period in 1950. Furthermore, in July and August the greatest densities were observed in the region between San Francisco and Point Conception. The 1950 season differed from 1949 also in that, from May to August inclusive, more birds were seen inshore and less at the offshore stations.

FACTORS AFFECTING ALBATROSS DISTRIBUTION

Variations in the numbers of *Diomedea nigripes* observed off the shores of North America have been attributed to various factors. Miller (1940) found these birds concentrated over a "cold tongue" of sea water, rich in nutrients and plankton. Thompson (1951) reported that the species was more abundant east of the 135th meridian, and showed that the increasing numbers of birds seen between

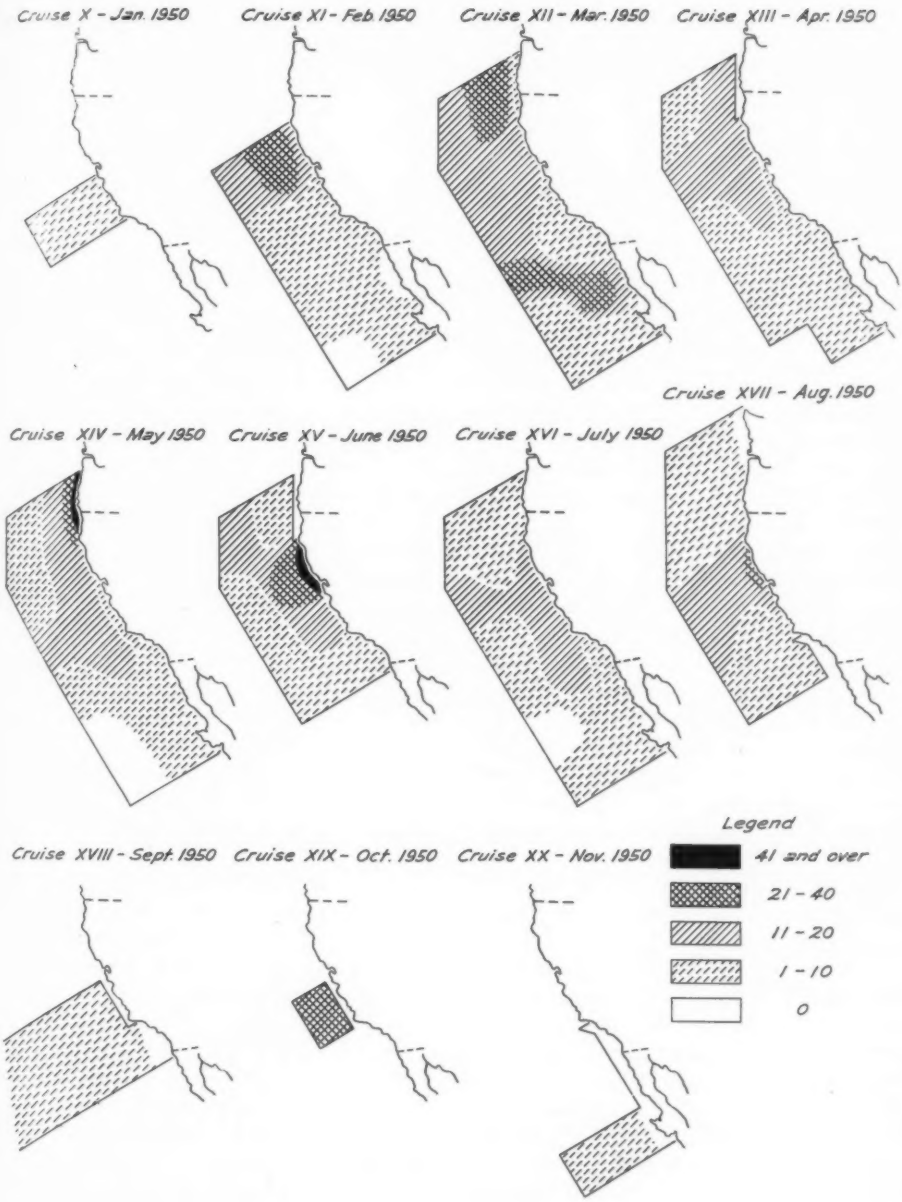
Cruise X - Jan. 1950
Cruise XI - Feb. 1950
Cruise XII - Mar. 1950
Cruise XIII - Apr. 1950
Cruise XIV - May 1950
Cruise XV - June 1950
Cruise XVI - July 1950
Cruise XVII - Aug. 1950
Cruise XVIII - Sept. 1950
Cruise XIX - Oct. 1950
Cruise XX - Nov. 1950
Legend
41 and over
21 - 40
11 - 20
1 - 10
0

FIG. 3. Distribution of Black-footed Albatrosses over the survey area during 1950. The contours were drawn according to the average numbers of birds per station in each block.

TABLE 2
AVERAGE ALBATROSS COUNTS AND PLANKTON VOLUMES FOR CRUISES 1 TO 5

BLOCK NUMBERS	REGION	MEAN NUMBERS OF ALBATROSSES	MEAN VOLUMES OF PLANKTON
7–9	Northern Calif.	19	214
10–12	Central Calif.	20	141
13–15	Southern Calif.	4	65
16–18	Baja Calif.	2	48

this line and the coast were associated with decreasing sea temperatures. Thompson also noted a direct relationship between the numbers of jellyfishes, observed by luminescence in the ship's wake at night, and the numbers of albatrosses counted during the day. He reasoned that jellyfishes, and hence albatrosses, were most abundant in the colder, more productive waters.

No consistent relationship between the total plankton volume in a standardized net haul and the numbers of albatrosses seen at the same station was observed on the 1949 and 1950 cruises. In a general way, however, the blocks in which the highest average numbers of birds were recorded were those in which the greatest average plankton volumes occurred. As illustrated in Table 2, the numbers of albatrosses and the volumes of plankton per unit volume of water[3] were greatest off the northern California coast, and least off southern and Baja California. It is not known whether this association indicates a causal relationship.

It is tempting to search for relationships between the pattern of albatross abundance and the distribution of the various physical, chemical, and biological factors recorded at the hydrographic stations. The albatross counts presumably are not subject to the criticism that is levelled at counts of plankton and other marine organisms, namely, that they represent only the standing crop, for these birds are almost completely free from predation while at sea (Miller, 1940; Yocom, 1947; McHugh, 1952). Nevertheless, strong and apparently highly significant statistical correlations can be obtained even with random numbers by trial and error methods. Inasmuch as there is no good biological evidence to suggest that albatross abundance and any of the physical, chemical, or biological factors are related, no correlations were sought.

In former years, when it was more abundant, the Pacific sardine (*Sardinops caerulea*) performed an annual migration from California waters to summer feeding grounds off the Pacific Northwest, sometimes ranging as far north as southeastern Alaska. There is indirect evidence, particularly in the 1949 observations, that the Black-footed Albatross performs a similar seasonal migration northward along the coast. If such a migration does occur, it may be in response to similar stimuli. Continued study of the distribution and movements of these birds may provide valuable clues to the question of varying sardine abundance and availability.

SUMMARY

Counts of Black-footed Albatross were recorded at all stations occupied during daylight on cruises of the California Cooperative Sardine Research Program in 1949 and 1950. The survey area was divided into blocks, and the counts per station within each block were averaged to derive indices of abundance. Birds were most abundant off California and Baja California during the spring months, and

[3] The plankton volumes were taken from an unpublished mimeographed summary prepared by the staff of the South Pacific Investigations of the U. S. Fish and Wildlife Service.

higher counts were recorded in the northern part of the region. There is some evidence of a northward migration along the coast in summer, similar to the summer migration of the Pacific sardine.

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Feeding Habits of the Sand Crab *Hippa pacifica* (Dana)[1]

DONALD C. MATTHEWS[2]

BURROWING SAND CRABS, *Hippa pacifica* (Dana), [*Remipes pacifica* Dana of Edmondson, 1925; *Emerita pacifica* (Dana) of Edmondson, 1946, and Bonnet, 1946], were observed feeding on Portuguese man-of-war (*Physalia utriculus* Eschscholtz) at Waimanalo Beach, Oahu, during the high surf of June, 1954. However, these sand crabs completely ignored another colonial hydrozoan, *Velella pacifica* Eschscholtz, present in the surf at the time. Viewing these two colonial hydrozoans from above, astute man could easily differentiate between the gas filled float of *Physalia* and the flattened, elliptical float and oblique sail of *Velella*, but less sagacious sand crabs, viewing these colonial hydrozoans from below, could not be expected to discern subtle differences of color or length of suspended zooids. This would be especially true during a high surf because of increased turbidity, yet, in no instance did I observe even a tentative approach to *Velella*. Even though *H. pacifica* has well developed eyes, the likelihood that selection of *Physalia* and rejection of *Velella* could result solely from visual discrimination is unlikely.

Whereas unselective feeding by antennal straining has been investigated in *Emerita*, insofar as could be ascertained, no published work on selective feeding in *H. pacifica* has been reported. Therefore the experiments reported on here were performed to investigate the method by which selective feeding is accomplished.

My appreciation is extended to Dr. Maxwell Doty, University of Hawaii, for the phycological determinations and to Dr. Fenner Chace, Jr., United States National Museum, for the identification of the Hawaiian sand crabs.

METHODS AND TECHNIQUES

A. Sand crabs collected during the high surf were usually attached (singly or in groups of five or six) to their captured *Physalia*. These crabs were removed and taken immediately to the laboratory where antennae, antennules and the contents of the dissected digestive systems were examined microscopically for the presence of minute plants and animals (exclusive of bacteria), an abundance of which would indicate unselective, filter feeding.

B. *Physalia* and *Velella* disappeared from the surf as the wind subsided but, washed high on the beach, stranded colonies formed an almost unbroken line as evidence of their previous abundance in the sea. These served as a ready source of food for subsequent experiments. Sand crabs likewise disappeared from the surf as the sea calmed, leaving the wave-washed region of the beach bare. Upon this region of the beach I tossed (1) pieces of algae (*Ulva fasciata* Delile, *Turbinaria ornata* J. Agardh, *Sargassum obtusifolium* J. Agardh, *Polyopes clarionensis* Sethchell & Gardner) broken to approximately the size of *Physalia;* (2) *Velella;* (3) pieces of commercial shrimp discarded by fishermen; and (4) *Physalia*.

Sand crabs which responded to any of these materials were collected and taken to the

[1] Contribution No. 69, Hawaii Marine Laboratory.
[2] Department of Zoology and Entomology, University of Hawaii.

laboratory where antennae, antennules and the contents of the dissected digestive systems were examined microscopically for evidence of filter feeding.

C. The methods employed in B were repeated, one week later. Sand crabs collected were taken to the laboratory and the antennae, antennules and contents of the dissected digestive systems examined microscopically for evidence of filter feeding.

D. Approximately equal portions of *Ulva*, *Velella*, shrimp and *Physalia* were separately ground with sand and sea water, filtered through number 40 mesh grit gauze and each filtrate (approximately 25 cc.) diluted to 1,000 cc. of sea water. Each solution was thrown on the thin film of a receding wave and the effects, if any, noted. For each solution, a new location on the beach was chosen. Again, sand crabs which responded to any of the solutions were taken to the laboratory where antennae, antennules, and the contents of the dissected digestive systems were examined microscopically for evidence of filter feeding.

E. Twenty-five male and 25 female sand crabs were collected and their compound eyes were removed leaving the major portion of the eye stalks intact. These blinded sand crabs were placed in a small tank and allowed one day to recover from operative shock, during which time they received additional sea water. *Physalia* was again ground in sand and sea water, filtered through number 40 mesh grit gauze and the filtrate (25 cc.) diluted with approximately 1,000 cc. of sea water. The diluted filtrate, colored with 0.5 grams of neutral red was placed in a clean, 1 liter bottle fitted with four discharge pipettes. Adjustment of a single Hoffman clamp permitted the simultaneous, drop by drop, delivery of the filtrate into four paper cups (300 cc. capacity) each of which contained beach sand, sufficient to cover the bottom 2 cm., and 75 cc. of sea water, sufficient to produce a water depth of 2 cm. Four sand crabs were simultaneously tested: (1) a control male, (2) a control female, (3) a test male, and (4) a test female; each in a separate paper cup. In no case was the filtrate introduced until all four sand crabs had buried themselves in the sand. Ten drops (approximately 0.5 cc.) of filtrate were simultaneously introduced into each of the four paper cups and the reaction time recorded. This was regarded as the interval from the instant the tenth drop struck the surface of the water, to any visible response by the crab. The observed times, both for control and test animals, was averaged for five separate trials. After each experiment, paper cups and contents were discarded. These blinded sand crabs and the controls were also examined microscopically for evidence of filter feeding.

F. The methods employed in E were repeated (with fresh paper cups, sand, and sea water) except that both the compound eyes and the antennae were removed.

G. The methods employed in E were repeated, except that the compound eyes and the antennules were removed.

H. An attempt was made to test crabs with compound eyes, antennae and antennules removed. However, only 24 (of 50) sand crabs survived the severe operative shock. Of these, over half remained on their backs on the surface of the sand, displayed little or no action and were dead the following morning. The colored *Physalia* solution was introduced to the remaining 12 survivors in the small tank and the results noted. These crabs were dead on arrival at the laboratory and I regret that the contents of their digestive systems were not examined microscopically. Male and female controls were run as before (E,F,G).

RESULTS

A. Microscopic examination of sand crab antennae and antennules collected during the high surf revealed sand grains but no organisms enmeshed in the setae. The dissected digestive systems, especially the pyloric caeca, were blue, gorged with nematocysts and the shredded remains of *Physalia* zooids. There were no microorganisms nor was there any

evidence, either from nematocysts or zooids, that *Velella* had been eaten.

B. As the wind subsided and *Physalia* and *Velella* no longer appeared in the surf, pieces of algae (*Ulva fasciata*, *Turbinaria ornata*, *Sargassum obtusifolium*, *Polyopes clarionensis*), *Velella* and shrimp tossed into the thin film of receding waves all failed to evoke any visible response from sand crabs but when *Physalia* was used, sand crabs emerged. Often 4 or 5 would seize a single colony simultaneously and, submerging, all take part in pulling it below. Others, often arriving at the scene too late and finding no prey, would quickly submerge as the wave receded. It was not difficult to collect 25 or more sand crabs by using a single *Physalia* colony over and over again in this manner. Microscopic examination of the antennae and antennules revealed sand grains but no organisms enmeshed in the setae. The dissected digestive systems were, as before, gorged with nematocysts and the blue remains of shredded *Physalia*, but no microorganisms were present.

C. As in B, when the waves of the calm sea broke on the beach, no crabs responded to *Ulva*. However, when *Velella*, commercial shrimp, and *Physalia* were tossed separately onto this region of the beach, crabs emerged. Microscopic examination of antennae and antennules again revealed sand grains but no organisms enmeshed in the setae. The dissected digestive systems were empty save for sand grains and what appeared to be mucus.

D. Filtered and diluted portions of ground *Ulva*, *Velella* and shrimp thrown on receding waves failed to evoke any visible response from the submerged crabs. However, when the *Physalia* filtrate was used sand crabs emerged, excitedly ran up and down the beach but, failing to locate the *Physalia*, quickly submerged. Microscopic examination of the antennae and antennules of these collected sand crabs revealed a few sand grains but no microorganisms enmeshed in the setae. Again the dissected digestive systems revealed nematocysts and the bluish remains of *Physalia* but no microorganisms.

E. Of the 50 sand crabs collected for this part of the experiment, only 18 males and 15 females survived the operative shock of eye removal. Many, even when molested, remained motionless on their backs; others righted themselves and, colliding one with another scurried around the tank. Finally, without any definite pattern of orientation, most submerged. Although the *Physalia* solution was clearly discernible as it left the four pipettes and entered the salt water of the paper cups its course became less apparent as it approached the sand so that determination of the exact moment of contact of filtrate and crabs was impossible. This condition was often further complicated by the spontaneous emerging of crabs before the first drop of filtrate could possibly have reached them. The addition of 0.5 grams of neutral red to the solution made it easy to follow the course of the filtrate. Sand crabs in all four cups emerged in great confusion during the introduction of the first six drops of filtrate. It was impossible for me to determine whether the control males and females or the blinded males and females responded more quickly. Microscopic examination of test and control crabs revealed only a few sand grains enmeshed in the setae of antennae and antennules. The digestive systems contained the remains of *Physalia* but there was no evidence of microorganisms.

F. Of the 50 sand crabs collected for this experiment, only 30 survived the operative shock of the removal of both the eyes and antennae. These exhibited about the same activities as those described in E. Again there was much confusion. Some turned over on their backs, whereas others, colliding one with another, hurried around and around the tank and finally, without special orientation, submerged. Compared to crabs having only the compound eyes removed the reaction of these crabs to the introduced filtrate was dilatory and weak. Often 3 to 5 minutes elapsed after

the tenth drop of *Physalia* solution was introduced before the crabs stirred. As in E the controls emerged before the tenth drop of *Physalia* solution was introduced. Microscopic examination of the antennules of operative and control crabs revealed only sand grains enmeshed in the setae and the contents of the dissected digestive systems again revealed unaltered nematocysts but no microorganisms.

G. Of the 50 sand crabs collected for this experiment about the same number (30) survived the operative shock of removal of eyes and antennules as survived the removal of eyes and antennae. These exhibited about the same activities as those described in F. There was the same confusion, the same colliding one with another, the same running around the tank and the same submerging without any special orientation. Again 3 to 5 minutes elapsed after the tenth drop of *Physalia* solution was introduced before the crabs emerged. No difference, either in time or in magnitude of response, was discernible between blinded sand crabs with antennae removed and blinded sand crabs with antennules removed. As in E the controls emerged before the tenth drop of *Physalia* solution was introduced. Microscopic examination of the antennae of test and control crabs revealed only sand grains, and the contents of the dissected digestive systems revealed only unaltered nematocysts.

H. After the tenth drop of the colored *Physalia* solution reached the 12 sand crabs that had survived the removal of eyes, antennae and antennules 15 to 21 minutes was required before any visible response occurred. As in previous experiments the controls emerged before the tenth drop of *Physalia* solution was introduced. For the most part the test crabs merely broke the surface of the sand, appeared to "tread water" momentarily, and then settled below the surface. As previously mentioned, these crabs were dead on arrival at the laboratory and their digestive systems were not examined. No microorganisms were present on the controls.

DISCUSSION

Gregarious sand crabs lie submerged in large "beds" with only eyes and antennules projecting above the shifting, wave-washed sand. In *Emerita*, for example, exceedingly long antennae, folded behind the maxillipeds (*vide* Weymouth and Richardson, 1912, pl. 1, fig. 7), are thrust out anterolaterally as waves recede; thus characteristic V-shaped ripples, which mark the "bed's" location, are formed (*vide* MacGinitie and MacGinitie, 1949, figs. 145–146, p. 302). However, Hawaii's only hippid (Edmondson, 1946, p. 265), has exceedingly short antennae (*vide* Dana, 1855, Atlas: Crustacea, pl. 25, fig. 7a), thus the characteristic V-shaped ripples result from water striking the antennules, rather than the antennae.

Weymouth and Richardson (*op. cit.* p. 11) conclude that microorganisms found in the stomach of *Emerita analoga* were strained from waves and that antennae and mouth parts "are remarkably adapted to this form of feeding, and unfitted for any other." In *Emerita analoga* the function of sensory antennal pits in feeding appears negligible as highly diversified materials generally reported from their stomachs (diatoms, radiolarians, foraminifera, spicules, one-celled algae and sand) are "about what would be obtained by unselective straining of the water along shore" (Weymouth and Richardson, *op. cit.*, p. 9).

In contrast to the unselective antennal straining of *Emerita*, feeding by *H. pacifica*, at least during high surf, is selective as evidenced by their acceptance of *Physalia* and their rejection of algae, shrimp, and *Velella*. Moreover, this selectivity is attributed, in part at least, to some sense other than sight for, although all experimental solutions probably appeared similar to the crabs, the *Physalia* solution alone evoked visible responses. Yet, so long as the eyes remained intact, selection based on some chemical sense (*vide* Moncrieff, 1946, p. 152; Ramsay, 1952, p. 85; and Prosser *et al.*, 1950, p. 453) although a strong

probability, could not be held entirely responsible for this phenomenon.

However as blinded *H. pacifica* reacted to *Physalia* solutions almost immediately, the presence of some selective chemical sense is demonstrated and, in light of similar research among other arthropods, attention was at once centered on antennae, antennules and mouth parts.

The removal of the antennae of blinded *H. pacifica* and the subsequent increase in reaction time (3–5 minutes) indicates that the chemical sense is in part located on these structures. Likewise, the removal of the antennules of blinded *H. pacifica* and the subsequent increase in reaction time (3–5 minutes) also indicates that the chemical sense is in part located on these structures. Inasmuch as the increased reaction time following the removal of the antennae so nearly approximates the increased reaction time following the removal of the antennules, one can conclude that these two structures are equally important in the degree of selectivity of the chemical sense.

To determine whether the chemoreceptors were limited to the antennae and antennules in blinded *H. pacifica*, both structures were removed. The increased reaction time (15–21 minutes) following the removal of both antennae and antennules indicates that probably there are chemoreceptors present on the still intact mouth parts, although they are much less effective than those of the antennae and antennules.

The chemoreceptors located on antennae and antennules of *H. pacifica* are therefore, responsible for the detection of *Physalia* during the high surf; the sense of sight being responsible primarily for actual location and subsequent seizure. This same chemical sense must also be responsible for detection, during calm seas, of shrimp and *Velella* which *H. pacifica* quite readily seizes once its digestive tract is empty and its preferred food scarce.

Neither the presence of shredded *Physalia* in the digestive tracts, nor the absence of minute organisms enmeshed in the setae of the antennae and antennules precludes the possibility of unselective feeding by *H. pacifica*, especially during the weeks of calm which often follow periods of heavy surf. Inasmuch as during periods of calm sand grains and mucus but no microorganisms have been found in the digestive tract of *H. pacifica* the question of unselective feeding remains unanswered.

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New Marine Chlorophyta from Southern Australia

H. B. S. WOMERSLEY[1]

THE SPECIES DESCRIBED herein were collected during the making of a survey of the marine Chlorophyta of southern Australia (from southwest Western Australia to eastern Victoria, including Tasmania). An account of all the known species of this region will be published separately. The marine green algae of southern Australia are far from completely known. In addition to these new species, a number of others which are probably undescribed are known to the writer, but material or knowledge of these is inadequate for publication.

Certain of these new species are of interest in showing the occurrence of what are more typically tropical or subtropical genera in southern Australia where the algal flora has warm temperate affinities, which become cold temperate on Victorian and Tasmanian coasts. Two species each of *Chlorodesmis* and *Cladophoropsis*, and *Dasycladus densus* are representatives of subtropical genera.

Abbreviations of herbaria mentioned in the following text are as follows: University of Adelaide (AD), Melbourne National Herbarium (MEL).

Order SIPHONALES

Family BRYOPSIDACEAE

Bryopsis minor n. sp.
Fig. 1

Fronds to 2 cm. high, tufted, much branched on all sides with numerous primary and secondary axes 150–350 μ thick, sometimes naked near the base, attached by rhizoidal processes. Branchlets slender, almost linear, to 3 mm. long and 12–55 μ wide, contracted at their base. Older axes without prominent branch scars. Chloroplasts numerous, round, 4–7 μ across, with a prominent central pyrenoid.

Thallus ad 2 cm. altus, fasciculus, undique ramosi cum multibus primis et secondariis axibus, 150–350 μ diam. Ramuli tenues, fere lineares, ad 3 mm. long. et 12–55 μ diam., constricti ad basem. Chloroplasti multi, circuli, 4–7 μ diam., cum uno medio pyrenoido.

TYPE LOCALITY: On black buoy, American River inlet, Kangaroo Island, South Australia.

TYPE: AD (No. A 4124, H. B. S. Womersley, September 6, 1946).

DISTRIBUTION: Known only from the type locality.

Although the genus *Bryopsis* is in urgent need of monographic revision, based on liquid preserved material and cultural studies, *B. minor* is distinct from all known Australian species of *Bryopsis*, and appears to differ from extra-Australian species. The closest species in form is possibly *B. monoica* Funk (see Hamel 1931: 393) from the Mediterranean.

Family CAULERPACEAE

Caulerpa ellistoniae n. sp.
Fig. 2

Fronds to 25 cm. high. Surculus stout, 2–3 mm. thick, smooth. Stems stout and naked below, irregularly branched. Axis of upper branches compressed, 1–2 mm. wide, bearing distichous rows of ramenta. Ramenta close together, compressed, 4–8 mm. long, about 1 mm. wide, tapering to both base and apex,

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FIG. 1. *Bryopsis minor* n. sp. Habit of branch (× 10).

with the lower edge more or less straight, the upper curved.

Thallus ad 25 cm. altus. Surculus crassus, 2–3 mm. diam., teres. Caules crassi, nudi infra, irregulariter ramosi. Axis ramorum superiorum compressa, 1–2 mm. lata, cum distichis ramentis. Ramenta compressa, 4–8 mm. long., circa 1 mm. lata, fusiformia; labrum inferior plus minus directum, labrum superior flexum.

TYPE LOCALITY: Elliston, on the west coast of Eyre Peninsula, South Australia.

TYPE: AD (No. A 13,426 H. B. S. Womersley, January 13, 1951). Isotypes distributed under this number.

DISTRIBUTION: Known only from the type locality (H. B. S. Womersley, January 13, 1951 and February 14, 1954).

C. ellistoniae is most closely related to *C. scalpelliformis*, but differs in having branched erect fronds and in the size and shape of the ramenta. In the former the ramenta are straight on the lower edge and curved on the upper, while the opposite usually occurs in *C. scalpelliformis*.

C. ellistoniae has been found only at Elliston in the drift after rough weather, in January, 1951, and February, 1954. It probably grows in deep rock pools on rough reefs.

Family CODIACEAE

Chlorodesmis australis n. sp.
Fig. 3

Thallus to 1.5 cm. high, medium to dark green, in loose tufts. Branching only at the base, with up to 4 dichotomies close together. Filaments constricted immediately above each dichotomy, above linear and simple, 25–45 μ wide. Cell wall thin, slightly thickened at basal constrictions. Base somewhat entangled, colourless, attached by short rhizoidal processes. Chloroplasts dense and numerous, round to ovoid, 1.4–2.7 μ across.

Thallus ad 1.5 cm. altus, viridis aut fusco-viridis, in fasciculis laxis. Rami solum ad basem dichotomi. Filamenta constricta supra omnia dichotoma, supra linearia et simplicia, 25–45 μ diam. Basis sub-implicata, sine colore, cum rhizoidis. Chloroplasti densi et multi, circuli aut ovati, 1.4–2.7 μ diam.

TYPE LOCALITY: Robe, South Australia (in pools at rear of rough reefs).

TYPE: AD (No. A 12,250, H. B. S. Womersley, August 28, 1949).

FIG. 2. *Caulerpa ellistoniae* n. sp. Type.

DISTRIBUTION: Known only from the type locality and from Pennington Bay, Kangaroo Island (H. B. S. Womersley, with *Chlorodesmis pusilla*, sub. no. A 7020), in pools at rear of rough reefs, January 1948.

This is a smaller plant with narrower filaments than any other species of *Chlorodesmis* (see Egerod 1952: 377 for the other species). It differs also in having the branching restricted to the basal region with constrictions just above each dichotomy.

Chlorodesmis pusilla n. sp.
Fig. 4

Thallus 0.5–1.5 cm. high, densely tufted, dark green, with a base of entangled colourless filaments with rhizoidal processes. Erect branches numerous, sparsely dichotomously or irregularly branched. Filaments 24–50 μ wide, linear but with undulate walls and usually constrictions shortly above the dichotomies, occasionally elsewhere. Cell wall thin, very slightly thickened at the constrictions. Chloroplasts dense, round to ovoid, 1–2.5 μ across.

Thallus 0.5–1.5 cm. altus, fasciculus, fusco-viridis, ad basem implicata filamenta sine colore et cum rhizoidibus. Rami erecti et multi, dichotomi aut irregulares. Filamenta 24–50 μ diam., linearia sed undulata, constricta supra dichotoma.

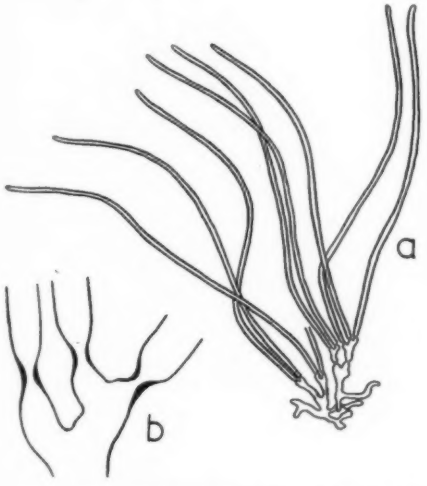

FIG. 3. *Chlorodesmis australis* n. sp. *a*, Habit of plant (× 11); *b*, detail of branching, showing constrictions above branch axil (× 150).

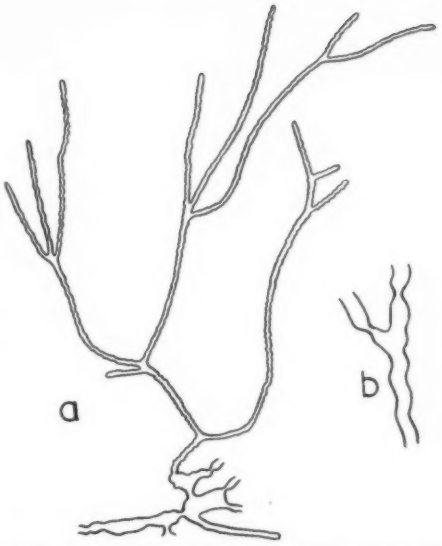

FIG. 4. *Chlorodesmis pusilla* n. sp. *a*, Plant with erect filaments arising from the rhizoidal base (× 11); *b*, part of a filament, showing undulating wall and constrictions above branch axil (× 50).

TYPE LOCALITY: Pennington Bay, Kangaroo Island, South Australia (in a shaded, rear pool on a rough reef).

TYPE: AD (No. A 7020, H. B. S. Womersley, January 4, 1948).

DISTRIBUTION: Known only from the type locality and from Vivonne Bay, Kangaroo Island (H. B. S. Womersley, No. A 15,460), in a shaded pool, south side of Ellen Point, August 29, 1950.

This species is similar to *C. australis* but forms more distinct and denser tufts, with branched erect filaments, and the cell walls are undulate.

Børgesen (1925: 77) separated *Pseudochlorodesmis* from *Chlorodesmis* on the lack of true dichotomous branching and the lack of constrictions above the point of branching. Branching which is not truly dichotomous is however found in *C. hildebrandtii* (see Egerod 1952, fig. 9), and *C. pusilla* shows similar branching. The two species here described, *C. pusilla* and *C. australis*, show constrictions

above each dichotomy in the basal filaments, and *C. pusilla* usually has constrictions above the upper branch axils. It seems likely that the characters separating *Pseudochlorodesmis* from *Chlorodesmis* may be of subgeneric rather than generic order.

Pseudocodium australasicum n. sp.
Figs. 5, 6

Thallus erect, subdichotomously or irregularly branched, to 6 cm. high, branches 1–2 mm. wide, compressed, branching partly (especially when young) in one plane, colour dark green. Holdfast small, of dense, colourless filaments. Thallus composed of a medulla of longitudinal, branched, coenocytic filaments, 13–28 μ thick, forming at the surface a cortical layer (12–27 μ wide) of short club-like branches, 4–7 μ wide, sub-palisade like; surface view of thallus showing ends of cortical branches, round to polygonal, 5–9 μ across, adhering together. Growth apical, by numerous longitudinal medullary filaments, slenderer than normal medullary filaments. Filaments with numerous nuclei and small discoid chloroplasts, 1–2.5 μ across.

Thallus erectus, subdichotome aut irregulariter ramosus, ad 6 cm. altus, rami 1–2 mm. lati, compressi; rami partim in una plana, fusco-viridis. Filamenta medullaria ramosa, 13–28 μ diam. Cortex 12–27 μ lata brevium, clavatorum ramorum (4–8 μ diam.)

TYPE LOCALITY: Point Sinclair (east end of Great Australian Bight) South Australia; uppermost sublittoral on a relatively calm reef near the old jetty.

TYPE: AD (No. A 13,618, H. B. S. Womersley, January 25, 1951). Isotypes distributed under this number.

DISTRIBUTION: Known only from the type locality and from a drift specimen about 10 miles east of Eucla, on the South Australian —Western Australian border (AD No. A 19,239, February 3, 1954).

P. australasicum is apparently a rare species. A small patch of a number of plants was found at Point Sinclair in January 1951, but this could not be located in February 1954.

This is the second described species of *Pseudocodium*, the type being *P. devriesii* Weber van Bosse (1896: 209, pl. 1. See also Levring 1938: 14, fig. 7, pl. 4, fig. 10) from South Africa. In general structure and method of growth *P. australasicum* agrees well with *P. devriesii*, but differs in its smaller size and the less well developed layer of cortical palisade-like branch ends. The formation of the cortical layer shows more affinity with *Halimeda*, as noted by Weber van Bosse and Levring for *P. devriesii*, than with *Codium*, to which it is considered allied by Gepp and Gepp (1911: 3).

Order SIPHONOCLADALES

Family SIPHONOCLADACEAE

Cladophoropsis magnus n. sp.
Fig. 7

Thallus forming large tangled masses up to 50 cm. across and 7 cm. thick, with the

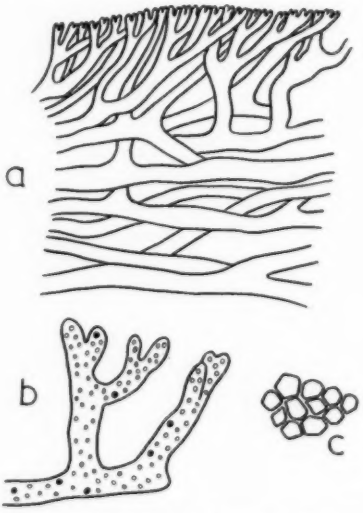

FIG. 5. *Pseudocodium australasicum* n. sp. *a*, Longitudinal section of thallus (× 280); *b*, detail of a medullary filament forming short cortical branches, showing nuclei and chloroplasts (× 500); *c*, surface view of cortical filaments (× 500).

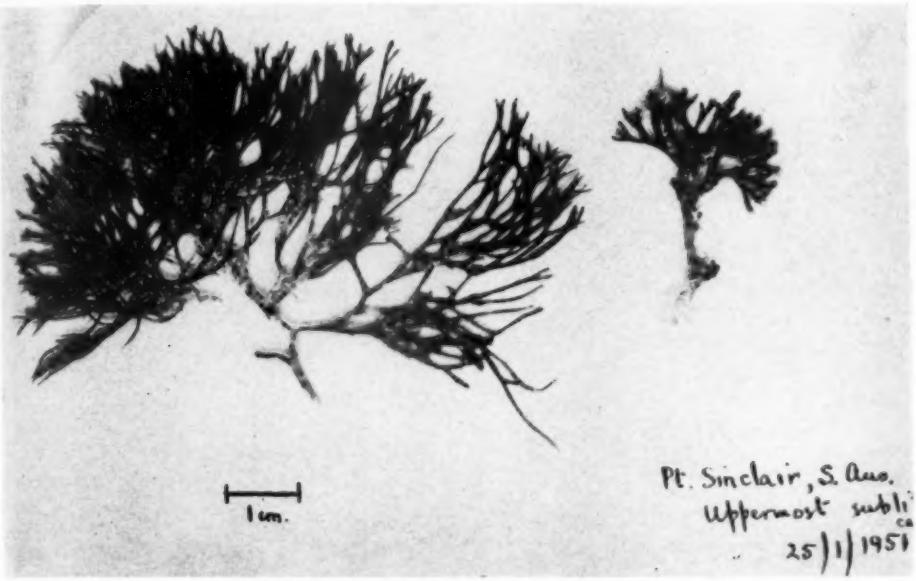

FIG. 6. *Pseudocodium australasicum* n. sp. Type.

filaments mostly erect in the upper part. Individual filaments several cm. long., 500–700 μ thick with a wall 6–10 μ thick, usually expanding slightly to a central thickest part from which clustered branches arise, one (rarely two) from each segment of the main filament. Cross septa close together in this branching region, far apart elsewhere. Lateral branches mostly simple, 170–350 μ wide, emitted from just below a septa, without a basal cross wall. Descending rhizoids absent.

Thallus magnus, ad 50 cm. latus et 7 cm. crassus. Filamenta plures cm. long., 500–700 μ diam., membrana 6–10 μ crassa, crassissima media parte cum pluribus ramis, unus ramus (interdum 2) segmento. Rami semper fere simplices, 170–350 μ diam., orti infra septum, sine septo ad basem. Rhizoides descendens non producentes.

TYPE LOCALITY: Smoky Bay, on the west coast of Eyre Peninsula, South Australia, drift.

TYPE: AD (No. A 13,615, H. B. S. Womersley, January 21, 1951). Isotypes distributed under numbers A 13,615, A 13,616.

DISTRIBUTION: Known only from Smoky and Denial Bays (in MEL), west coast of Eyre Peninsula.

C. magnus is one of the largest species of *Cladophoropsis*, especially in the size of the whole thallus. It shows some resemblance to *C. herpestica* (Montagne) Howe, which occurs on exposed coasts of Eyre Peninsula, but differs in its broader filaments, localisation of branching, and absence of descending rhizoids. Specimens in the Melbourne National Herbarium from Denial Bay, under the *nomen nudum* of *Cladophora tietkinsii* Sonder, show that Sonder had recognised this as a distinct species.

Cladophoropsis bulbosa n. sp.
Figs. 8, 9

Thallus erect, densely tufted, to 10 cm. high, arising from a matted bulbous base

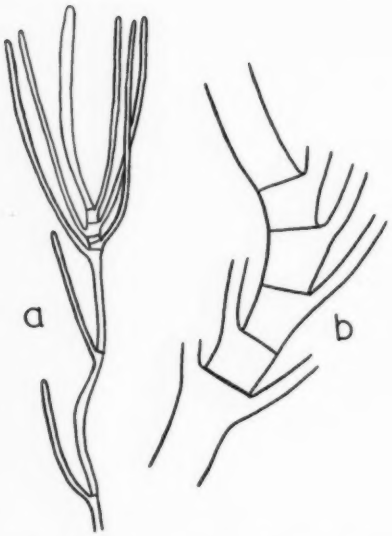

FIG. 7. *Cladophoropsis magnus* n. sp. *a*, A single filament showing branching (× 2.5); *b*, central part of a filament with crowded branches (× 12).

(1–2 cm. high) of entangled rhizoids. Upper filaments sparsely branched, of uniform width throughout, (300–) 400–570 μ wide; wall lamellate, 6–10 μ thick; main filaments without septa, lateral filaments with a single septum at their base. Rhizoidal basal filaments irregularly branched, sometimes swollen in places, 60–250 μ wide, with or without septa at base of branches.

Thallus erectus, fasciculus, ad 10 cm. altus, cum bulbo ad basem rhizoidum implicatorum (1–2 cm. altus). Filamenta interdum ramosa, linearia (300–) 400–570 μ diam., membrana lamellata, 6–10 μ crassa; filamenta prima sine septis, filamenta lateralia cum septo ad basem. Rhizoides irregulariter ramosi, interdum tumite, 60–250 μ lati.

TYPE LOCALITY: Queenscliff, Victoria.

TYPE: MEL (see Fig. 9).

DISTRIBUTION: Known only from the type locality and from Pennington Bay, Kangaroo Island (outer pools on rough reefs, AD No. A 2223, H. B. S. Womersley, January 25, 1944) and drift (AD No. 2818, H. B. S. Womersley, January 28, 1946).

This species had been recognised as distinct by Sonder, but never published. Sonder's specimen (called *Cladophora* (*Aegagropila*) *bulbosa*) (in MEL) is the best seen and is chosen as the type. Apparently it is a rare plant, known from only three collections. The habit and dimensions separate it readily from other described species of *Cladophoropsis*, which are listed by Papenfuss (1950: 211).

Order DASYCLADALES

Family DASYCLADACEAE

Dasycladus densus n. sp.
Figs. 10, 11

Fronds with 1–16 simple, erect axes, arising from a basal holdfast attached by short rhizoidal processes. Axes to 6 cm. high, 2–4 mm. thick, consisting of a central siphon (to 1 mm. broad) with a thick lamellate wall, bearing crowded whorls of branches, 10–12 branches per whorl. Branches with segments of 3 orders; primary segments producing from their apex 4 (3–5) secondary segments, these in turn forming 2 (–3) tertiary segments.

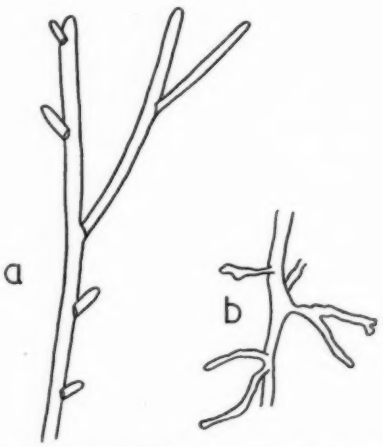

FIG. 8. *Cladophoropsis bulbosa* n. sp. *a*, Upper branch of thallus (× 8); *b*, rhizoidal base of a filament (× 8).

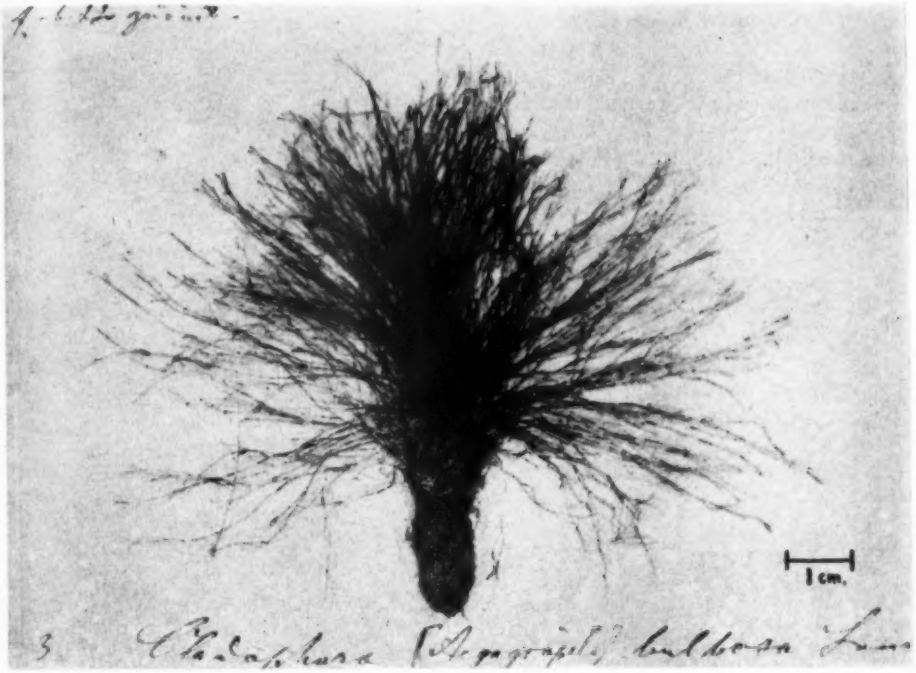

FIG. 9. *Cladophoropsis bulbosa* n. sp. Type.

Primary segments elongate to pyriform, 400–700 μ long and 200–400 μ wide, communicating with the axial siphon; secondary segments elongate—linear, 450–560 μ long and 120–200 μ wide; tertiary segments clavate, 130–400 μ long and 100–130 μ wide; secondary and tertiary segments often lost.

Thallus cum 1–16 simplicibus et erectis axibus, ex haptero ad basem. Axes ad 6 cm. alti, 2–4 mm. lati, compositi siphonis medii (ad 1 mm. diam.), cum membrana crassa lamellata, ferentes densa verticilla 10–12 ramorum. Rami cum segmentis trium ordinum; prima segmenta cum 4 (3–5) secondariis segmentis ad apicem; secondaria segmenta cum 2 (–3) tertiis segmentis. Prima segmenta longa ad pyriformem, 400–700 μ long.; 200–400 μ diam.; secondaria segmenta elongata, 450–560 μ long.; 120–200 μ diam.; tertia segmenta clavata, 130–400 μ long., 100–130 μ diam.; secondaria et tertia segmenta saepe defecta.

TYPE LOCALITY: Point Fowler, in the northeast part of the Great Australian Bight, South Australia. (Uppermost sublittoral in sandy hollows, with weak to moderate wave action.)

TYPE: AD (No. A 19,437, H. B. S. Womersley, February 6, 1954). Isotypes distributed under this number.

DISTRIBUTION: Known only from the type locality.

This is the only species of the typically tropical-subtropical genus *Dasycladus* known from southern Australia. It is closely related to the type species, *D. clavaeformis* (Roth) Agardh from the Mediterranean, Canary Islands and West Indian region, but differs in the size of the branch segments and in the rounded ends to the tertiary segments (the

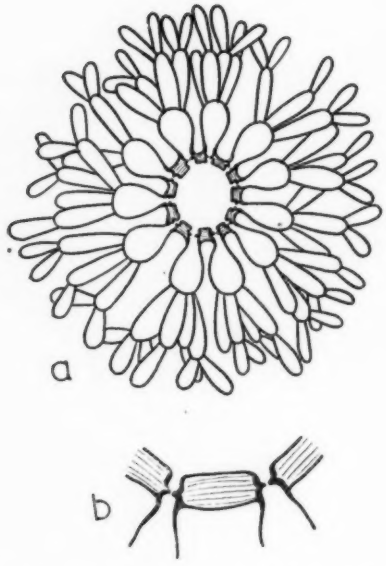

FIG. 10. *Dasycladus densus* n. sp. *a*, Cross section of the thallus showing whorl of branches (some secondary and tertiary segments lost) (× 19); *b*, part of central axis showing connection of primary segments (× 85).

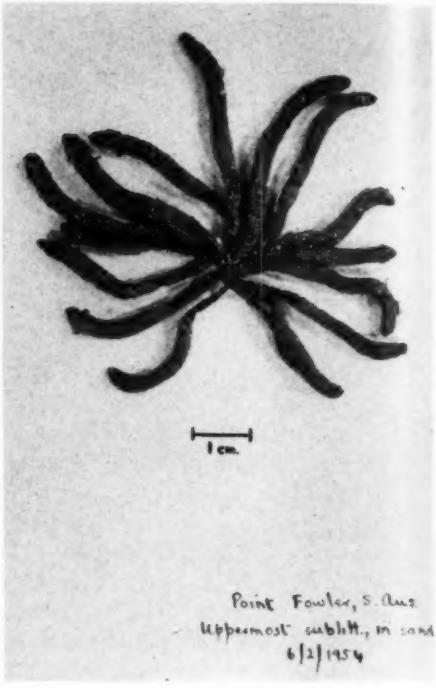

FIG. 11. *Dasycladus densus*. n. sp. Type.

latter being apiculate in *D. clavaeformis*). The reproduction of *D. densus* is at present unknown, but with such similarities in vegetative features there is little doubt that it should be placed in *Dasycladus*.

Chloroclados australasicus Sonder (1871: 35, pl. 5, f. 1–6) from Cape Yorke, northern Australia, was distinguished from *Dasycladus* by the presence of cysts in the sporangia and differences in the branch whorls. The type of this species is in the Melbourne National Herbarium and agrees well with Sonder's figures; however, no cysts are apparent in the sporangia, i.e., in the spherical inflated cells on the ends of the primary segments. Until preserved or fresh specimens can be examined, it seems justified to refer *C. australasicus* to *Dasycladus* as Cramer (1887: 37) has done.

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A Revision of the Surgeon Fish Genera *Zebrasoma* and *Paracanthurus*[1]

JOHN E. RANDALL

THE SURGEON FISHES (Acanthuridae), like many of the families of tropical marine fishes, are in need of thorough taxonomic study on a world-wide basis. In the present paper, which is one of a series on the classification of the family (see Randall, 1955), the species of two of the genera, *Zebrasoma* and *Paracanthurus*, are considered. The question of whether *Zebrasoma flavescens* (Bennett) is or is not a dichromatic species is discussed in detail. Specimens of the three rare species of *Zebrasoma*, *Z. gemmatum* (Cuvier and Valenciennes), *Z. xanthurum* (Blyth), and *Z. rostratum* (Günther) were examined, and the validity of these species is confirmed. The postlarval *Zebrasoma* and early juvenile *Paracanthurus* are figured for the first time.

An attempt is made to give complete synonymies. Mere listings or records of species with insufficient data to permit identification are generally not included among the synonyms. When first citations are given without a locality, this information was not supplied by the author(s). A locality is listed with later citations of a species only when it appears that the author examined specimens from this locality. In the synonymies misidentifications are indicated by a period after the scientific name.

In making dorsal and anal fin ray counts, the last two rays are counted as one only when they share the same basal element. All rudiments are included in the gill raker counts. In addition to the usual counts of gill rakers (herein designated anterior gill rakers), counts of the more ridge-like rakers along the inner surface of the first gill arch (posterior gill rakers) are given.

Most of the work on this paper was done at the United States National Museum, and the author is indebted to Leonard P. Schultz, Ernest A. Lachner, and Robert H. Kanazawa for their kind assistance. All of the *Zebrasoma* and *Paracanthurus* in the collections of the Academy of Natural Sciences of Philadelphia, Museum of Comparative Zoology at Harvard College, California Academy of Sciences, Stanford Natural History Museum, Bernice P. Bishop Museum, and University of Hawaii were examined.

ZEBRASOMA Swainson

Zebrasoma Swainson (1839: 256). (Type species by monotypy, *Acanthurus velifer* Bloch.)

Body compressed, ovate, depth contained 1.4 to 2.1 times in standard length (this and other proportional measurements based on specimens over 50 mm. in standard length); head length 2.9 to 3.7 in standard length; snout produced; caudal peduncle with a single folding spine on each side, fitting into a shallow depression; length of caudal spine 3 to 6 in head length; least depth of caudal

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peduncle 2.7 to 3.6 in head length; mouth small, terminal; jaws equal; teeth close-set, compressed, denticulate, 10 to 20 in upper jaw, 12 to 22 in lower jaw; dorsal and anal fins elevated; dorsal fin with IV to V slender spines and 23 to 33 rays; anal fin with III spines and 19 to 26 rays; pectoral fin 2.7 to 3.3 in standard length; pectoral fin rays 14 to 17, the uppermost a short bony spicule, the next long and unbranched; pelvic fin with I spine and 5 rays, its length contained 3.5 to 4.5 in standard length; caudal fin truncate, with 16 principal rays; eye diameter (in specimens of 120 to 150 mm. in standard length) 3.5 to 4.5 in head length (except long-snouted specimens of *Z. rostratum*); interorbital slightly rounded, 2.9 to 3.4 in head length (also with the exception of *Z. rostratum*); gill openings restricted to sides; gill membranes attached to isthmus; anterior gill rakers 8 to 12; posterior gill rakers 9 to 13; scales very small, elevated, and with stout ctenii; 22 vertebrae; stomach elongate and thin-walled.

Zebrasoma is generally considered as an Indo-West-Pacific genus. Guichenot (1853: 122), however, recorded it (as *Acanthurus scopas* Cuvier and Valenciennes) from Cuba. He mentioned the very prominent snout, the great body depth, the small rough scales, and the patch of dense setae caudally on the body. The color was noted as gray-violet with brown spots; there were lines of white marks on the side and a white band in the humeral region. His choice of words in the brief description was very similar to that of Cuvier and Valenciennes (1835: 245). No meristic data were given, but there is little question that this author was describing a *Zebrasoma*. Günther (1861: 343) considered Guichenot's citing of *scopas* from Cuba as a "most remarkable fact." L. Bertin kindly checked for the specimen in the Paris Museum for me but could find no record of it. It seems possible that Guichenot's record is an error. To my knowledge there has been no further mention of *Zebrasoma* from the Atlantic.

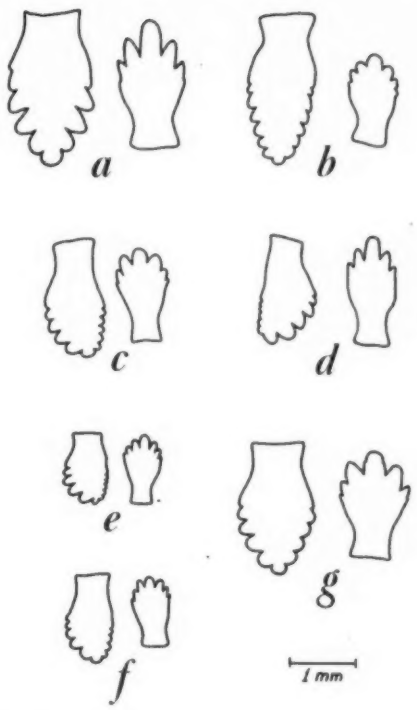


FIG. 1. Camera lucida drawings of upper and lower teeth of *Zebrasoma* and *Paracanthurus*. Teeth were taken from right side of jaws near center and drawn in inner or lingual view; the upper is to the left in each pair. *a*, *Z. veliferum*, 171 mm. specimen, Gilbert Islands; *b*, *Z. gemmatum*, 121 mm. specimen, Mauritius; *c*, *Z. xanthurum*, 181 mm. specimen, Red Sea; *d*, *Z. rostratum*, 140 mm. specimen, Tuamotu Archipelago; *e*, *Z. flavescens*, 100 mm. specimen, Johnston Island; *f*, *Z. scopas*, 108 mm. specimen, Philippine Islands; *g*, *P. hepatus*, 155 mm. specimen, Philippine Islands.

KEY TO THE SPECIES OF ZEBRASOMA

1a. Dorsal rays IV, 28 to 33; anal soft rays 22 to 26; longest dorsal ray 2.1 to 2.5 in standard length (in specimens over 50 mm. in length); body with alternate pale and dark, vertical bands . . . . . **Zebrasoma veliferum**

1b. Dorsal fin rays IV or V, 23 to 28; anal soft rays 19 to 24; longest dorsal ray 2.8 to 3.7 in standard length (in specimens

over 50 mm. in length); body without alternate pale and dark, vertical bands . . 2

2a. Dorsal fin rays V (rarely IV), 23 to 26; anal soft rays 19 to 22; denticulations on lateral edge of upper teeth decidedly smaller than medial denticulations (Fig. 1*c–f*); body and dorsal and anal fins without spots (except longitudinal lines on *scopas* broken into fine spots anteriorly on the body) 3

2b. Dorsal fin rays (based on 2 specimens) IV, 28; anal soft rays 24; denticulations on both edges of teeth of equal size (Fig. 1*b*); body and dorsal and anal fins with numerous white (said to be blue in life) spots . . . . **Zebrasoma gemmatum**

3a. Caudal fin abruptly pale (yellow in life) and in sharp contrast to dark body color; sheath of caudal spine black; profile of head from eye to upper lip only slightly concave . . . . . **Zebrasoma xanthurum**

3b. Caudal fin same color as body; sheath of caudal spine white; profile of head from eye to upper lip markedly concave (as snout is strongly produced) 4

4a. Body and fins not uniform black; lower teeth with 7 denticulations, the centermost only slightly larger than adjacent ones (Fig. 1*c, f*) 5

4b. Body and fins uniform black; lower teeth with 5 denticulations, the centermost about twice as large as adjacent ones (Fig. 1*d*) . . . . . **Zebrasoma rostratum**

5a. Body pale (yellow in life); dorsal soft rays 24 to 26 (usually 25); anal soft rays 19 to 22 (usually 20 or 21) . . . . . **Zebrasoma flavescens**

5b. Body brown with numerous pale longitudinal lines; dorsal soft rays 23 to 25 (usually 24); anal soft rays 19 to 21 (usually 19 or 20) . . **Zebrasoma scopas**

Zebrasoma veliferum (Bloch)
Fig. 1*a*; Fig. 2; Fig. 3; Pl. 1

Acanthurus velifer Bloch (1797: 106, pl. 427, fig. 1) (seas of East Indies); Lacépède (1802: 547); Rüppell (1828: 58, pl. 15, fig. 2) (Red Sea); Cuvier (1829: 224); Cuvier and Valenciennes (1835: 251) (Mauritius, East Indies, Red Sea); Günther (1861: 344) (Fiji Islands); Playfair in Playfair and Günther (1866: 57) (Zanzibar); Klunzinger (1871: 505) (Red Sea); Day (1876: 207) (seas of India); Sauvage (1891: 344) (Madagascar).

Acanthurus Velifer Bloch and Schneider (1801: xxxviii, 214).

Acanthurus (*Harpurus*) *velifer* Klunzinger (1884: 85).

Acanthurus Desjardinii Bennett (1835: 207) (Mauritius).

Acanthurus desjardinii Günther (1861: 344) (Mauritius); Playfair in Playfair and Günther (1866: 57) (Zanzibar).

Acanthurus Ruppellii Bennett (1835: 207) (Red Sea); Bleeker (1855: 451) (Kokos Island, Sumatra).

Acanthurus rüppellii Günther (1861: 345) (Red Sea).

Acanthurus Blochii Bennett (1835: 207) (India).

Zebrasoma velifer Swainson (1839: 256); Herre (1934: 63) (Philippine Islands).

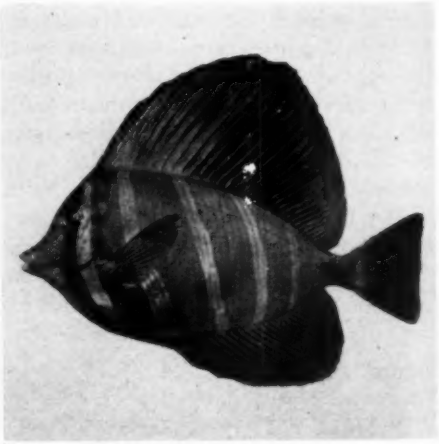


FIG. 2. *Zebrasoma veliferum* (Bloch), 183 mm., Gilbert Islands (reproduced from a 35 mm. Kodachrome transparency).

Acanthurus suillus Cuvier (1829: 224) (after Renard, 1718, vol. I, pl. 14, fig. 82); Cuvier and Valenciennes (1835: 254) (Mauritius); Günther (1861: 345).

Acanthurus élégant Liénard (1843: 69) (Mauritius) (reference from Sauvage, 1891: 344).

Acanthurus hypselopterus Bleeker (1854: 327) (Larantuka, East Indies); Günther (1861: 344); Günther (1873: 117) (Samoa, Palau Islands and Misol, East Indies).

Acanthurus maristarum Thiollière *in* Montrouzier (1856: 458) (Island of Woodlark).

Acanthurus (*Harpurus*) *hypselopterus* Steindachner (1901: 494, pl. 4, fig. 1) (Honolulu).

Acanthurus kipas Bleeker (1854: 327) (East Indies).

Harpurus hypselopterus Bleeker (1863: 252) (Flores, East Indies).

Harpurus Rüppelli Bleeker (1863: 235) (Ternate, East Indies).

Harpurus Desjardini Bleeker and Pollen (1874: 96) (Mauritius).

Acanthurus virgatus Vaillant and Sauvage (1875: 283) (Hawaiian Islands).

Acanthurus fasciatus Bliss (1883: 53) (Mauritius).

Zebrasoma hypselopterum Jenkins (1903: 479) (Honolulu); Ogilby (1916: 174, pl. 23) (Queensland, Australia).

Zebrasoma veliferum Jordan and Evermann (1905: 396, fig. 173) (Honolulu); Jordan and Seale (1906: 356) (Samoa); Kendall and Radcliffe (1912: 143) (Mangareva); Jordan and Jordan (1922: 66) (Honolulu); Herre (1927: 443, pl. 11, labelled *Zebrasoma viliferum*) (Philippine Islands); Fowler (1928: 275, pl. 32, fig. B); Fowler and Bean (1929: 255) (Philippine Islands and East Indies); Schmidt (1930: 104) (Riu Kiu Islands); Fowler (1931: 346) (Honolulu); Herre (1936: 249) (Solomon Islands); Hiyama (1943: 95, pl. 21, fig. 58); Aoyagi (1943: 205, pl. 4, fig. 6, teeth only) (Riu Kiu Islands); Schultz (1943: 166) (Phoenix Islands and Samoa Islands); de Beaufort (1951: 167, fig. 28) (New Guinea and Ambon, East Indies); Schultz and Woods *in* Schultz, *et al.* (1953: 640) (Marshall Islands); Harry (1953: 152) (Raroia, Tuamotu Archipelago).

Zebrasoma veliforum novae caledoniae Borodin (1932: 88) (New Caledonia).

Hepatus coccinatus von Bonde (1934: 449, fig. 3) (Zanzibar).

Zebrasoma velifera Marshall (1950: 195) (Cocos-Keeling Islands).

Dorsal rays IV, 28 to 33 (in Oceania usually 31 or 32); anal rays III, 22 to 26 (in Oceania usually 24 or 25); pectoral rays 15 to 17 (usually 16); anterior gill rakers 8 to 11 and posterior gill rakers 9 or 10 (12 specimens from nine localities over the range of the species); the number of teeth increase slowly with age: a 25 mm. specimen from the Gilbert Islands had 10 upper and 12 lower teeth; 51, 80, and 94 mm. specimens had 12 upper and 14 lower teeth; 128, 154, and 168 mm. specimens had 14 upper and 16 lower teeth; 233 and 245 mm. specimens had 16 upper and 18 lower teeth.

Dorsal fin very elevated, longest soft dorsal ray 2.1 to 2.5 in standard length; fourth dorsal spine 2.5 to 2.8 in standard length; body depth 1.8 to 2 in standard length (1.4 in 25 mm. specimen); no patch of stiff bristles on side of body anterior to caudal spine. The posterior end of the caudal spine is not as broadly joined to the body in *veliferum* as in other species of *Zebrasoma*.

Color (in alcohol) brown with alternate, near-vertical, dark and light (pale yellow in life) bands; the first dark band passes through the eye and angles backward to the origin of the pelvic fins; the first pale band runs from the nape across the opercle just behind the eye to the pelvic region; the remaining four or five pale bands on the body are about one-third to one-fourth as broad as the intermediate brown areas, and each is bissected by a narrow dark line; within the intermediate brown areas alternate lines of dark and light are perceptible, the dark lines tending to

TABLE 1
FIN RAY COUNTS OF SPECIMENS OF SPECIES OF *Zebrasoma* FROM VARIOUS LOCALITIES

SPECIES AND LOCALITY	DORSAL SPINES		DORSAL SOFT RAYS											ANAL SOFT RAYS								PECTORAL RAYS			
	IV	V	23	24	25	26	27	28	29	30	31	32	33	19	20	21	22	23	24	25	26	14	15	16	17
veliferum																									
Hawaiian Is.	11									3	4	4							3	7	1		1	9	1
Phoenix Is.	3										1	2								2	1			3	
Samoa Is.	3											3								2	1			3	
Marshall Is.	6										3	3							2	4			1	5	
Gilbert Is.	10										4	4	2						4	5	1		3	7	
Society Is.	4								1		2	1							1	3				4	
Mangareva	1										1									1				1	
Philippine Is.	24									5	8	11						2	5	17			9	15	
East Indies	3										1	2								2	1			3	
Mauritius	8						1	6	1								1	6	1					8	
Zanzibar	1							1										1						1	
Egypt, Red Sea	7							2	3	1	1						2	4	1				1	5	1
gemmatum																									
Mauritius	2							2											2					1	1
xanthurum																									
Egypt, Red Sea		7		6	1									4	3								7		
rostratum																									
Tuamotu Arch.	1	10	1	7	3									1	10								11		
Society Is.		2		2											2								2		
flavescens																									
Hawaiian Is.	2	56	1	13	32	12								2	19	34	3					1	54	3	
Johnston I.		5		2	3										2	3							4	1	
Wake I.		3			3										1	2							2	1	
N. Marshall Is.		1				1										1							1		
Marcus I.		1			1											1							1		
Mariana Is.		6		1	2	3										5	1						4	2	
scopas																									
N. Marshall Is.	1	7		6	2										7	1							8		
Gilbert Is.		3	1	2										1	2								3		
Samoa Is.		21	1	14	6									4	15	2						2	18	1	
Society Is.		14	1	8	5									2	11	1						3	10	1	
Riu Kiu Is.		1	1											1									1		
Philippine Is.	1	41	9	28	5									10	32							7	33	2	
East Indies		13	2	9	2									2	11							1	12		
Mauritius		4		3	1										4								4		

break into spots antero-ventrally on the body; head and chest with small pale spots; dorsal and anal fins dark with curved pale lines which may be broken into spots; caudal fin dark with faint pale spots; caudal spine in a blackish area.

The low dorsal and anal fin ray counts (Table 1) of the Red Sea, Zanzibar, and Mauritius specimens and slightly different color (the very narrow vertical pale lines on the body are more conspicuous) suggest that the form in the Indian Ocean and Red Sea might be regarded as a different subspecies from that in the East Indies and Oceania. Many more specimens from various parts of the Indian Ocean are needed to establish the nature of subspecific differentiation in this species.

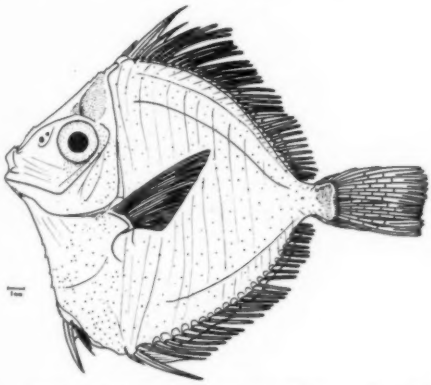


FIG. 3. Postlarval *Zebrasoma veliferum*, 18 mm., Hawaiian Islands. Drawn with the aid of a camera lucida by H. Randall.

The 18 mm. postlarval specimen of *Z. veliferum* (Fig. 3) was collected by Joseph E. King of the Pacific Oceanic Fishery Investigations on Dec. 26, 1951 offshore from Kaneohe, Oahu. It was taken in an oblique haul from the surface to about 200 meters with a 6 foot trawl.

The juvenile specimen (Pl. 1) was taken with rotenone by the author from a channel of 3 to 5 foot depth at Onotoa Atoll, Gilbert Islands. The area was sandy with occasional heads of *Heliopora*.

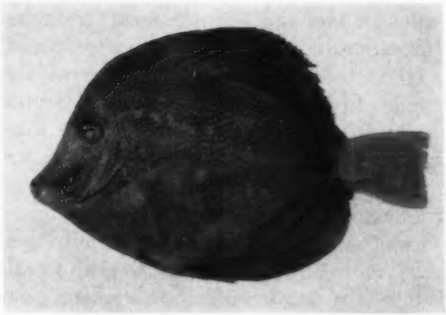


FIG. 4. *Zebrasoma gemmatum* (Cuvier and Valenciennes), 121 mm., Mauritius.

The largest specimen seen by me was 275 mm. in standard length. De Beaufort (1951: 169) recorded total length to 395 mm., which would be about 315 mm. in standard length.

Although widespread in the tropical Indian and West Pacific Oceans, this species is not as abundant as many of the other surgeon fishes. Schultz and Woods (1953: 641) state that a large school was observed entering shallow water in the Marshall Islands; the individuals of the school were swimming at times with their dorsal fins out of water like a sail. I have occasionally observed *Z. veliferum* underwater in the Hawaiian Islands and in the Gilbert Islands, but only as solitary individuals. I have never seen the dorsal fin elevated.

Zebrasoma gemmatum
(Cuvier and Valenciennes)
Fig. 1*b*; Fig. 4

Acanthurus gemmatus Cuvier and Valenciennes (1835: 255) (Mauritius); Günther (1861: 343); Sauvage (1891: 343) (Madagascar?).

Harpurus gemmatus Bleeker and Pollen (1874: 96) (Mauritius).

Zebrasoma gemmatum Fowler and Bean (1929: 258).

Dorsal rays IV, 28; anal rays III, 24; pectoral rays 16 or 17; anterior gill rakers 12 and posterior gill rakers 11; 121 mm. specimen

with 15 upper and 17 lower teeth; 179 mm. specimen with 18 upper and 20 lower teeth.

Longest soft dorsal ray 3 to 3.1 in standard length; fourth dorsal spine 4.5 to 5.9 in standard length; body depth 1.7 to 1.9 in standard length; no patch of setae on side of body anterior to caudal spine. All counts and measurements are based on two specimens.

Color (in alcohol) brown with numerous white spots on head, body, dorsal and anal fins, base of pectoral fin, and very faintly on caudal fin (these spots tend to be round on fins, head, and dorsal part of body, but elongate elsewhere on the body); caudal fin pale.

Cuvier and Valenciennes (1835: 256) stated that the caudal fin was yellow. Sauvage (1891: 344) (after Liénard) described the spots on this fish as blue.

Z. gemmatum is known only from the island of Mauritius and possibly Madagascar.

Zebrasoma xanthurum (Blyth)
Fig. 1*c;* Fig. 5

Acanthurus xanthurus Blyth in Kelaart (1852: appendix p. 50) (Ceylon); Günther (1861: 343); Playfair *in* Playfair and Günther (1866: 57, pl. 8, fig. 4) (Aden); Klunzinger (1871: 504) (Red Sea); Day (1876: 207).

Acanthurus (*Harpurus*) *xanthurus* Klunzinger (1884: 85).

Zebrasoma xanthurum Fowler and Bean (1929: 262).

Dorsal rays V, 24 or 25; anal rays III, 19 or 20; pectoral rays 15; gill rakers (from one specimen): anterior 11, posterior 13; upper teeth 18 to 20; lower teeth 22.

Longest soft dorsal ray 3.4 to 3.7 in standard length; fifth dorsal spine 3.9 to 4.1 in standard length; body depth 1.7 to 1.85 in standard length; an oval, velvety patch on side of body anterior to caudal spine. All measurement and meristic data except gill raker counts based on seven specimens, 120 to 181 mm. from the Red Sea.

Color (in alcohol) dark gray to black with small spots on head, nape, and chest (these spots pale on two of the specimens and dark on the others); entire caudal fin abruptly yellowish white just posterior to caudal spine; dorsal, anal, and pelvic fins dark gray; pectoral fin with basal two-thirds dark gray, outer one-third pale.

Blyth (in Kelaart, 1882: appendix p. 50) described the color in life from a 7.5 inch specimen as ". . . wholly black with bright golden-yellow tail, and a tinge of the same upon the pectorals."

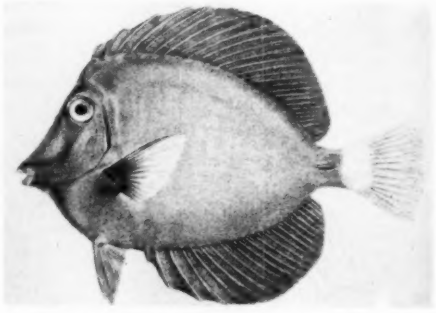


FIG. 5. *Zebrasoma xanthurum* (Blyth), (after Playfair, 1866).

This species is difficult to separate from *Z. scopas* and *Z. flavescens* on any basis other than color. The snout is slightly less produced in *Z. xanthurum* and, for a comparable size, the velvet like area on the side much less developed. It seems likely that *Z. xanthurum* attains a larger size. Four of the seven specimens from the Red Sea range from 145 to 181 mm. in standard length. The largest *Z. scopas* I have seen is 149 mm. in standard length (from the Society Islands). Of over 100 adult specimens in the United States National Museum from the Philippines and East Indies, the largest is 145 mm. and only nine exceed 115 mm. The largest of many *Z. flavescens* examined by me is a Hawaiian specimen 149 mm. in length.

Zebrasoma xanthurum is thus far reported only from Ceylon, the Gulf of Aden, and the Red Sea.

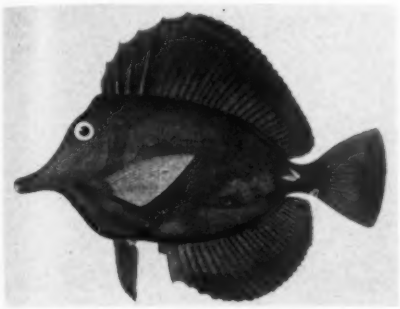


FIG. 6. *Zebrasoma rostratum* (Günther), (after Günther, 1873).

Zebrasoma rostratum (Günther)
Fig. 1*d;* Fig. 6

Acanthurus rostratus Günther (1873: 117, pl. 66, fig. B) (Society Islands).

Zebrasoma rostratum Fowler (1928: 275); Harry (1953: 152) (Raroia, Tuamotu Archipelago).

Zebrasoma (*Laephichthys*) *rostratum* Fowler and Bean (1929: 262).

Laephichthys rostratus Fowler (1938: 127) (Apataki, Tuamotu Archipelago); Fowler (1952: 25, fig.).

Dorsal rays V (rarely IV), 23 to 25; anal rays III, 19 or 20; pectoral rays 15; anterior gill rakers 10 and posterior gill rakers 9 or 10 (from 2 specimens, Society Islands); 84 and 121 mm. specimens had 16 upper and lower teeth; a 166 mm. specimen had 16 upper and 18 lower teeth, and a 170 mm. specimen 18 upper and lower teeth.

Longest soft dorsal ray 3 to 3.7 in standard length; fifth dorsal spine 3.7 to 4 in standard length; body depth about 2 in standard length; patch of setae in front of the caudal spine may or may not be present (two of seven specimens which could be sexed had well-developed setae and were males; the others lacked this bristle area and were females; thus it is possible that this is a sexual character in this species).

The long snout was believed to be the most characteristic feature; however, examination of a series of 10 specimens in the Stanford Natural History Museum, collected by R. R. Harry from Raroia Atoll in the Tuamotus, revealed considerable variability in snout length. The ratio of snout length (measured from tip of upper teeth to nearest edge of eye) to standard length (tip of snout to base of caudal fin) ranged from about 3 to 5. This variability is not associated with growth nor does it appear to be related to sex.

I did not observe the dorsal spines to be noticeably stouter than those of other species of *Zebrasoma*, although Garrett's drawing (in Günther, 1873, reproduced herein as Fig. 6) shows them to be.

Color (in alcohol) entirely black except membranes of pectoral fin which are clear, the caudal spine which is hyaline with a white sheath, and in some specimens a faint pale longitudinal band in the posterior half of the dorsal and anal fins. Harry (1953: 152) gives the life color as solid black with white caudal spine.

Günther described *Acanthurus rostratus* from Garrett's notes and his painting of a 7.5 inch specimen. It has been presumed that the specimen is not in existence; however, I found two collected by Garrett, both 7.5 inches in total length, at the Museum of Comparative Zoology. It seems likely that one of these was the basis for the figure and therefore should be considered as the type.

Fowler (1938: 128) thought that the velvety patch in front of the caudal spine was removed by the publishers of "Fische der Südsee" from the painting. In this he is probably in error, for both of the Garrett specimens are females and lack this setous area.

Zebrasoma rostratum is known only from the Society Islands and two islands in the Tuamotus. Harry collected his specimens from lagoon shore reefs at Raroia and observed the species also on lagoon coral heads.

Zebrasoma flavescens (Bennett)
Fig. 1*e;* Fig. 7

Acanthurus flavescens Bennett (1828: 41) (Oahu); Günther (1873: 116, pl. 76, fig. B) (Hawaiian Islands); Steindachner (1901: 493) (Honolulu).

Zabrasoma agaña Seale (1901: 110) (Guam).

Zebrasoma flavescens Bryan and Herre (1903: 134) (Marcus Island); Jordan and Evermann (1905: 397, pl. 59) (Oahu); Jordan and Seale (1906: 355); Jordan and Jordan (1922: 66) (Hawaii); Fowler and Ball (1925: 19) (Johnston Island); Fowler (1928: 274, pl. 32, fig. A) (Hawaiian Islands, Johnston Island, Marcus Island); Aoyagi (in part) (1943: 203) (Riu Kiu Islands); Schultz and Woods *in* Schultz *et al.* (in part) (1953: 641) (Bikini Atoll, Marshall Islands).

Scopas flavescens Jenkins (1903: 480) (Honolulu and Puako Bay, Hawaii).

Dorsal rays V (rarely IV), 23 to 26 (usually 24 or 25); anal rays III, 19 to 22 (usually 20 or 21); pectoral rays 14 to 16 (usually 15); anterior gill rakers 8 to 12 and posterior gill rakers 11 or 12 (based on a total of 12 specimens from the Hawaiian Islands, Johnston Island, Wake Island, Bikini Atoll, Marcus Island, and Guam); a 25 mm. transforming specimen from Saipan had 12 upper and 14 lower teeth; a 77 mm. specimen collected by Schultz, Hiatt, and Brock at Bikini (U.S.N.M. No. 140586) had 15 upper teeth and 18 lower teeth; a 149 mm. specimen from Hawaii had 18 upper and 22 lower teeth.

The following proportional measurements were made on 15 specimens from 75 to 149 mm. in standard length: length of longest dorsal ray 2.8 to 3.8 in standard length; length of fifth dorsal spine 2.95 to 4.0 in standard length; body depth 1.4 to 1.75 (2.4 in 26 mm. juvenile specimen); a well-developed dense patch of setae posteriorly on the side of the body, progressively more prominent in larger specimens.

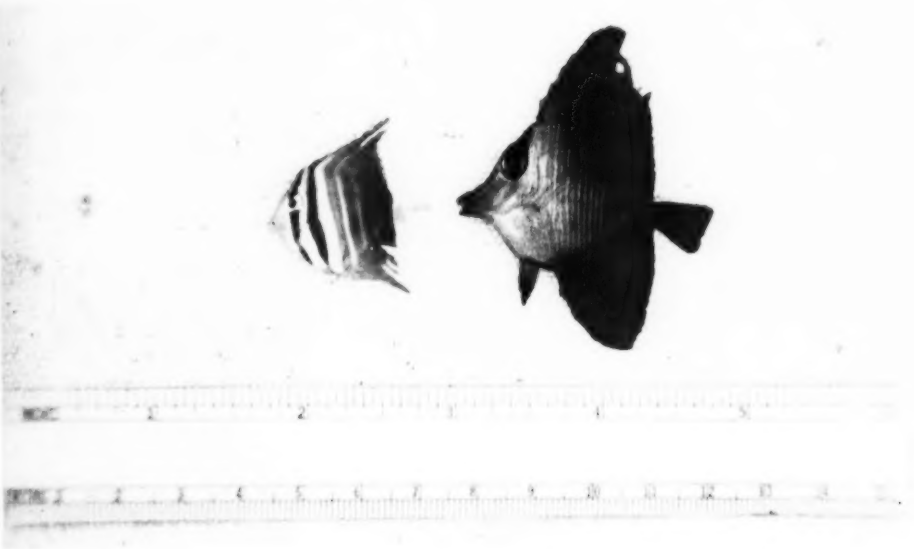
Color (in alcohol) uniform yellowish white, in life bright chrome yellow. Upper edge of pectoral fin with a very narrow dark margin; sheath of caudal spine white. Preserved specimens often show a long, faint whitish pale band running backward and slightly downward from just behind the upper end of the gill opening.

FIG. 7. *Zebrasoma flavescens* (Bennett), 120 mm., Hawaiian Islands (reproduced from a 35 mm. Kodachrome transparency).

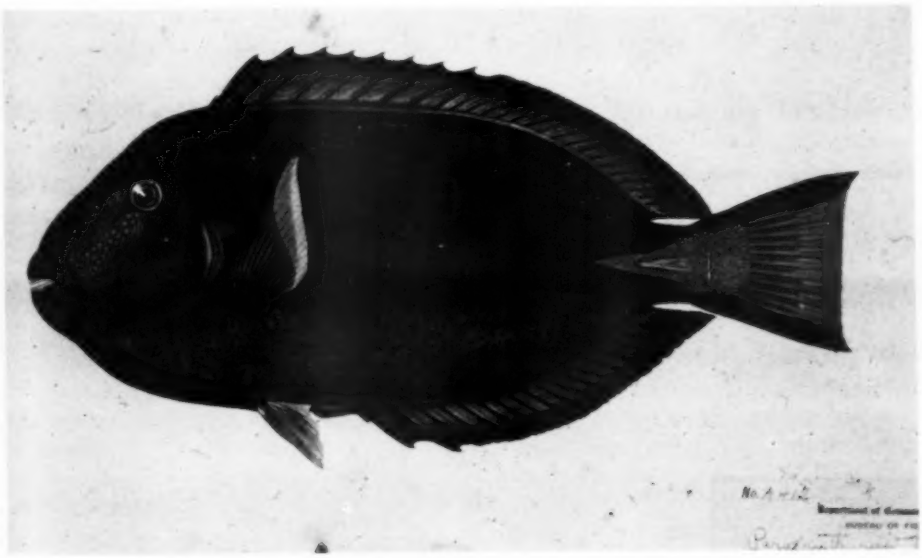
Two of three yellow specimens of *Z. flavescens* (U.S.N.M. No. 140567) collected by L. P. Schultz from Johnston Island are a light dusky color over the back and head and there is a slight concentration of brownish pigment anteriorly in the dorsal fin. The yellow Bikini specimen shows this same diffuse marking in the fin. Still, this is but a slight departure from the usual pure yellow color.

This brightly-colored species is abundant in the Hawaiian Islands. Brock (1954: 302) calls attention to the interesting fact that it is much more common on leeward sides of islands than windward. His figure 1 shows the relative abundance of this fish (as *Zebrasoma*) in nine different localities around the islands of Hawaii and Oahu.

Jordan and Evermann (1905: 398) believed *Acanthurus virgatus* Vaillant and Sauvage to be the young of *Z. flavescens* and placed it in the synonymy of the latter. *A. virgatus* had vertical dark bars on the body and was probably a juvenile *Zebrasoma veliferum*. Juvenile



Young of *Zebrasoma veliferum* (left) and *Z. scopas*, Gilbert Islands (from a Kodachrome by the author).



Paracanthurus hepatus, 204 mm., Philippine Islands (from an unpublished painting in the files of the U. S. Natl. Mus.).

Z. flavescens display no dark markings of any kind. A 21.5 mm. transforming specimen taken at a depth of 40 feet off Waikiki, Oahu, on June 3, 1952 was bright yellow in color like adults.

Except for one sight record in the Tuamotus (Harry, 1953), *Z. flavescens* appears to be confined to the northern part of the tropical Pacific. I have seen specimens only from the Hawaiian Islands, Johnston Island, Wake Island, Marcus Island, northern Marshall Islands, and the Marianas (including the type of *Z. agaña* Seale from Guam, kindly loaned by E. H. Bryan of the Bishop Museum, and two small bright yellow specimens collected by Eugenie Clark at Saipan). See section on *Z. scopas* for further discussion of *Z. flavescens*.

Zebrasoma scopas (Cuvier)
Fig. 1*f*; Pl. 1

Acanthurus scopas Cuvier (1829: 224) (after Renard, 1718, vol. 1, pl. 40, fig. 210) (Neira, Province of Banda); Cuvier and Valenciennes (1835: 245, pl. 290) (New Guinea); Bleeker (1851: 348) (Solor, East Indies); Thiollière *in* Montrouzier (1856: 459) (Island of Woodlark).

Acanthurus rhombeus von Kittlitz (1834: 194, pl. 13, fig. 6) (Ulea Island = Woleai Atoll, Caroline Islands); Günther (1861: 342) (Aneityum, New Hebrides and Ceram, East Indies); Playfair *in* Playfair and Günther (1866: 57) (Zanzibar).

Acanthurus altivelis Cuvier and Valenciennes (1835: 249) (Indian Ocean and Mauritius).

Harpurus scopas Swainson (1839: 256).

Acanthurus goramensis Bleeker (1858: 208) (Goram, East Indies); Günther (1861: 343); Jatzow and Lenz (1898: 514, pl. 36, fig. 11) (Zanzibar).

Harpurus rhombeus Bleeker (1863: 271) (Timor, East Indies).

Acanthurus flavescens. Günther (1873: 116, pl. 76, fig. A) (Tahiti); Sauvage (1891: 342) (Madagascar).

Zebrasoma rhombeum Jordan and Seale (1906: 355) (Samoa); Jordan and Seale (1907: 34) (Panay, Philippine Islands); Jordan and Richardson (1908: 270) (Cagayancillo, Philippine Islands); Fowler (1928: 275) (Indo-Pacific, but not Hawaiian Islands, Johnston Island, or Marcus Island).

Zebrasoma flavescens. Jordan and Fowler (1902: 555) (Okinawa); Herre (1927: 441) (Philippine Islands); Fowler and Bean (1929: 258) (Philippine Islands and East Indies); Schmidt (1930: 103) (Riu Kiu Islands); Giltay (1933: 86) (East Indies); Herre (1934: 63) (Philippine Islands); Herre (1936: 248) (Society Islands, New Hebrides, Solomon Islands); Poll (1942: 11, fig. 3) (Tahiti); Aoyagi (in part) (1943: 203, pl. 8, fig. 3) (Riu Kiu Islands); Schultz (1943: 167) (Samoa Islands); de Beaufort (1951: 170) (Java); Schultz and Woods *in* Schultz *et al.* (in part) (1953: 641, pl. 66, fig. B) (Marshall Islands); Harry (1953: 152) (Raroia, Tuamotu Archipelago).

Zebrasoma rostratum. Jordan and Seale (1906: 356) (Samoa).

Zebrasoma supra-alba Fowler (1946: 198, fig. 70) (Riu Kiu Islands).

Dorsal rays V (rarely IV), 23 to 25 (usually 24); anal rays III, 19 to 21 (usually 19 or 20); pectoral rays 14 to 16 (usually 15); anterior gill rakers 9 to 12 and posterior gill rakers 10 to 13 (based on a total of 12 specimens from the Marshall Islands, Samoa, Society Islands, Philippine Islands, and East Indies); a 30 mm. specimen from the Gilbert Islands had 12 upper and 14 lower teeth; a 74 mm. specimen from the Philippines had 14 upper and 16 lower teeth; a 145 mm. specimen from the Philippines had 18 upper and 22 lower teeth.

The following proportional measurements were made on 15 specimens from 52 to 145 mm. in standard length: length of longest dorsal ray 2.7 to 3.6 in standard length; length of fifth dorsal spine 2.9 to 3.9 in standard length; body depth 1.5 to 1.7 in standard length (2.2 in a 30 mm. juvenile); oval-

shaped brush-like patch of setae on sides, very prominent in larger specimens where it extends nearly half way to the base of the pectoral fin from the caudal spine (this velvet-like region first becomes apparent in specimens of 65 to 70 mm. in standard length).

Color (in alcohol) brown with numerous, thin, light gray, irregular, horizontal lines on the body which are broken into discrete spots anteriorly and on head; on small specimens (about 45 to 65 mm. in length) the lines are entirely broken up on the body. Specimens smaller than 45 mm. have narrow vertical pale lines on the body between which spots are aligned vertically. In most specimens, regardless of length, a dusky white band of about the diameter of a pupil of eye in width extends posteriorly from a point just behind the upper edge of the gill opening over half the distance to the caudal spine. Sheath of caudal spine white; median fins brown; pectoral fin membranes hyaline, rays light brown; upper edge of unbranched pectoral ray with a narrow black line.

Color (in life) dark brown, yellowish brown anteriorly, with numerous, narrow, wavy, light blue longitudinal lines on the body, breaking up to small blue dots on nape, chest, and head (no linear pattern being evident on the latter); all fins except pectorals dark brown; pectorals clear with dusky orange rays and a narrow black upper margin. This color note was obtained from an 88 mm. specimen collected by me from a recess in a stand of dead staghorn coral in the lagoon of Onotoa Atoll, Gilbert Islands.

Although colors of olive or dark green and black have been given for the species, the majority of the records of the basic life color are brown. The other colors may represent variability which is possible in individual specimens. Other acanthurids are known for the ability to alter their hues (Townsend, 1929). *Ctenochaetus striatus* (Quoy and Gaimard), also a brown, blue-lined species, may appear almost black or distinctly olivaceous when alive.

The young of *Z. scopas* and *Z. veliferum* are compared in the upper figure of Plate 1. The photograph is of fresh specimens captured at Onotoa Atoll.

Schultz and Woods (1953: 642) reported that this species was found in or close to deep water in the Marshall Islands. I observed adults in about 8 feet of water in the Onotoa lagoon and on the lee reef of Butaritari Atoll in the Gilbert Islands; however, they were seen infrequently.

The largest specimen in the museum material which I have examined measured 149 mm. in standard length.

Varied opinions as to the relationship of *Z. scopas* and *flavescens* have been expressed in the literature.

Günther (1873: 117) united *Acanthurus rhombeus* (= *Z. scopas*) with *flavescens*, regarding the yellow form in Hawaii as probably a case of albinism. Jordan and Seale (1906: 355) (1907: 34) stated that the two are probably the same species, though they retained both names. Herre (1927: 443), Fowler and Bean (1929: 260), Aoyagi (1943: 204), Schultz and Woods (1953: 152), and others have asserted their belief that these are color forms of a single species. Jordan and Fowler (1902: 556) wrote, "Probably the typical *flavescens* is found in deep water, the variety *rhombeum* living near shore." Certainly this does not seem to be true, for neither form appears restricted to any particular depth on the reef. I have observed *Z. flavescens* in Hawaii in from about 3 to 90 feet of water. *Z. scopas* (as here defined) is known from Zanzibar to southern and western Oceania. In spite of extensive collecting and underwater observation in the Hawaiian Islands, Johnston Island, and Wake Island by W. A. Gosline, V. E. Brock, myself, and others, no specimens of *Z. scopas* (the so called brown phase of *Z. flavescens*) have been seen, although the bright yellow *Z. flavescens* is abundant. The few museum specimens from Marcus Island and Guam are pale, presumably yellow in life, and hence *Z. flavescens*.

I have examined 167 specimens from the Philippines, East Indies, Gilbert Islands, Samoa Islands, Society Islands, and Mauritius, and all were brown. Jordan and Seale (1906: 356) had 50 specimens from Samoa and saw none yellow in color. Fowler (1928: 274) recorded *Z. flavescens* from the Hawaiian Islands, Johnston Island, Samoa, Marcus Island, and Raiatea and described the species from preserved specimens as fuscous-black with fine grayish lines. Of his specimens only those from Samoa and Raiatea were of this color; the rest were pale yellowish.

Only from Bikini Atoll in the northern Marshall Islands have I seen both yellow and brown specimens from the same area. Of 14 specimens only one was yellow. Aoyagi (1943: 204) reported both yellow and brown and intermediate forms from the Riu Kiu Islands, however, he mentioned that there was some geographical separation. R. R. Harry (1953: 152) stated that he observed one yellow specimen underwater at Raroia Atoll in the Tuamotus but took only the dark form. Upon discussing this sight record with Harry, I learned that he was unaware of the solid bright yellow color of the young of *Acanthurus olivaceus* Bloch and Schneider. He than stated that he could not be certain that the specimen he saw was *Z. flavescens* and not *A. olivaceus*.

My efforts to distinguish the yellow *Z. flavescens* and the brown *Z. scopas* on other grounds than color met with the usual failure except for fin ray counts (Table 1) which provide a partial separation, the counts of *Z. flavescens* being higher. One might say that this meristic difference is due to the colder water of the northern part of Oceania to which the yellow "phase" seems to be restricted. However, the water of the Mariana Islands is as warm as the warmest areas of the Pacific (more specimens are needed from this region however, to be certain that the fin ray counts are really higher), and the fin ray counts of *Z. scopas* from the Society Islands, which are about as far south as the Hawaiian Islands are north and have sea surface temperatures which are almost as cool as Hawaii (Hydrographic Office, 1944), show no increase (Table 1). Also *Z. veliferum* does not exhibit any obvious increase in ray counts in the Hawaiian Islands.

In view of the available data, I do not believe that *Z. flavescens* and *Z. scopas* can be considered as color varieties of one polymorphic species. If they were color varieties, at least an occasional brown specimen should have turned up in areas like the Hawaiian Islands, or yellow ones from the southern or western tropical Pacific or Indian Oceans. More important, one would not expect the fin ray counts of both phases to be different. Two other possibilities exist: the brown and yellow forms are full species or they are subspecies. My data are not yet sufficient to decide with assurance which is the case. At the present time I favor considering the two as species, although I may be placing too much emphasis on the single yellow specimen from Bikini with higher fin ray counts than brown specimens from the same atoll. This one yellow specimen might have been carried there as a larva from a *Z. flavescens* area such as Wake Island. If this were true, the case for subspecies would be strengthened.

The claim made by Aoyagi that yellow, brown, and intermediate forms occur in the Riu Kius is difficult to assess and should be checked. The intermediate forms were described as yellowish brown with minute spots. This is normal coloration for subadult and juvenile *Z. scopas*; thus this author might not have observed true intermediate forms at all. If the "geographical separation" which he mentioned is north-south within this island chain and true intermediate forms were found in a region of contact of the yellow and brown, the best explanation would be in terms of subspecies.

I examined the type of *Zebrasoma supra-alba* Fowler from the Riu Kiu Islands at the Academy of Natural Sciences of Philadelphia. The unique feature of the anterior part of the

dorsal fin being white appears to be caused by damage to the specimen. The fin membranes of the first four spines are completely torn off. A white area does appear posterior to the fourth spine to about the middle of the fin, but this seems to be due to a stripping off of the pigmented epidermis. The fin ray counts of this specimen are given in Table 1 for the Riu Kiu Islands under the heading *scopas*.

PARACANTHURUS Bleeker

Paracanthurus Bleeker (1863: 252). (Type species, *Acanthurus hepatus* (Linnaeus) Bloch and Schneider = *Teuthis hepatus* Linnaeus as restricted by Cuvier and Valenciennes.)

The characteristics of the genus are those of the single known species.

Paracanthurus hepatus (Linnaeus)
Fig. 1*g*; Fig. 8; Pl. 3

Teuthis hepatus Linnaeus (in part) (1766: 507) (after Seba, 1734, and Valentijn, 1724) (sea of the Indies).

Acanthurus hepatus Bloch and Schneider (in part) (1802: 11); Cuvier and Valenciennes (1835: 183, pl. 288) (Mauritius and New Guinea); Bleeker (1854: 325) (Flores, East Indies); Günther (1861: 341) (Ambon, East Indies); Günther (1873: 115, pl. 75) (Gilbert Islands); Day (1876: 206) (seas of India).

Acanthurus theuthis Lacépède (1802: 547, 549).

Acanthurus Theuthis Shaw (1802: 377).

Acanthurus triangulus Cuvier and Valenciennes (1835: 189) (after Vlaming); Günther (1861: 341).

Paracanthurus hepatus Bleeker (1863: 252) (Ceram, East Indies); de Beaufort (1951: 131, fig. 25) (Pulu Weh and Banda, East Indies).

Colocopus lambdurus Gill (1885: 279); Jordan and Seale (1906: 355).

Acanthurus teuthis Weber (1913: 318) (Banda, East Indies).

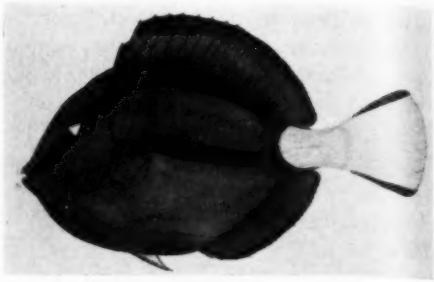


FIG. 8. *Paracanthurus hepatus* (Linnaeus), 30 mm., Schouten Islands, East Indies (photograph of an unpublished painting by Frederick M. Bayer).

Paracanthurus lambdurus Fowler (1926: 140); Herre (1927: 435, pl. 13, fig. 3) (Philippine Islands); Herre (1934: 63).

Paracanthurus theuthis Fowler (1928: 273); Fowler and Bean (1929: 205, fig. 10) (Philippine Islands and East Indies); Fowler (1931: 344) (Palau Islands); Aoyagi (1943: 202, pl. 8, fig. 1, pl. 4, fig. 8) (Riu Kiu Islands); Smith (1949: 239, pl. 33, no. 607) (Mozambique).

The following is based on the one catalogued adult specimen in the United States National Museum (No. 146636, 204 mm., Philippine Islands): body compressed, elliptical, the depth contained 2.3 in standard length; head length contained 3.75 in standard length; a broad groove on each side of caudal peduncle with a single movable spine, sharp anteriorly, broadly joined to body posteriorly; length of caudal spine 4 in head length; least depth of caudal peduncle 2.4 in head length; mouth very small, terminal; jaws equal; teeth small, close-set, denticulated, 14 in upper jaw and 17 in lower jaw (a 140 mm. specimen from the Gilbert Islands and now in the Bishop Museum, Honolulu, had 12 upper and 14 lower teeth); all spines of fins stout; dorsal and anal fins not elevated, longest dorsal ray 8.2 in standard length; dorsal fin rays IX (the first very short), 19 or 20; anal fin rays III (the first very short), 18 or

19 (based on four specimens from the Philippines, one from the Gilbert Islands, and two from Mauritius); pectoral fin rays 16; pelvic fin rays I, 3 (the first soft ray closely applied to the spine); length of pectoral fin 4.3 in standard length; length of pelvic fin 7.5 in standard length; caudal fin with 16 principal rays, truncate with upper and lower lobes slightly projecting; length of caudal fin 5.6 in standard length; eye small, 6 in head length; interorbital highly arched, 3.4 in head length; gill openings well-restricted to sides; gill membranes confluent and very broadly attached to isthmus; scales of body thick, each with many short ctenii on upper surface (ctenii on scales in a small area just anterior to caudal spine about three times as long as elsewhere on body); scales on head, especially anteriorly, enlarged to tuberculated plates; 22 vertebrae; stomach oval with moderately thick walls.

Color (in alcohol) light grayish brown (blue in life) with a broad black area on back, enclosing an oval light gray-brown region at the tip of the pectoral, and extending forward dorsally to eye; a long light yellowish brown triangle (bright yellow in life) with apex anterior to caudal spine and base formed by truncate posterior margin of caudal fin; upper and lower lobes of caudal fin black, this color confluent with the black area of the back; pectoral fin dark gray on first two principal rays and basal two-thirds of remaining rays; dorsal and anal fins with basal half yellowish gray and distal half dark gray; pelvics yellowish gray.

Fowler and Bean (1929: 206, fig. 10) show variation of color markings of this species with age.

Smaller than any of the specimens figured by Fowler and Bean is one, 30 mm. in standard length, collected in shallow water at Biak, Schouten Islands, in April, 1945, by Frederick M. Bayer. His unpublished painting is reproduced as Figure 8. The specimen had a bright blue body, yellow tail, and black markings as shown.

Acanthurus triangulus Cuvier and Valenciennes was described from an old drawing by Vlaming. It appears to be *Paracanthurus hepatus* with the black and yellow colors reversed.

P. hepatus is known from East Africa to the Philippines and the Riu Kiu Islands. It does not appear to range throughout the tropical Pacific, the only record from this vast area being that of Günther (1873) from the Gilbert Islands.

Three different species of surgeon fishes of five prelinnaean authors were cited by Linnaeus (1766: 507) under the specific name *hepatus*. Cuvier and Valenciennes (1835: 183) were the first to realize this confusion and used the name for the East Indian species of Seba (1734: 104, pl. 33, fig. 3) which is easily recognized as *Paracanthurus* (see de Beaufort, 1951: 133, for further discussion). The Atlantic species of *Acanthurus* usually called *hepatus* must therefore be given another specific designation. *Acanthurus chirurgus* (Bloch) is the first available name.

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A New Copepod of the Genus *Calanus* from the Northeastern Pacific with Notes on *Calanus tenuicornis* Dana[1]

THOMAS E. BOWMAN[2]

WHILE ENUMERATING COPEPODS from net hauls made in 1949 and succeeding years off the California coast in connection with the California Cooperative Oceanic Fisheries Investigation (CCOFI), it was observed that specimens with characters agreeing with those given in the literature for *Calanus tenuicornis* Dana were of two types. One form, limited to the southern portion of the area investigated, had a longer and narrower body and relatively longer appendages. The other, more stubby, form had a wider distribution, with maximum numbers to the north. The problem of whether these two forms are environmentally determined or whether they differ genetically on the specific or subspecific level invited investigation. The results of this study, presented herein, have led to the conclusion that the more stubby form is Dana's *C. tenuicornis*, and the elongate form is a new species.

Calanus tenuicornis was first described by Dana (1853: 1069) from the Central North Pacific. His description was brief, dealing chiefly with the first antenna. He figured (1855, pl. 73, fig. 10 a, b) a dorsal view of the adult female with the first antennae attached and detail of the distal end of the first antenna. Giesbrecht (1892, pls. 6–8) provided several additional illustrations. Figures published by most authors following Giesbrecht (van Breemen, 1908, fig. 8, a–d; Pesta, 1920, fig. A, 3; Rose, 1933, fig. 12; Farran and Verwoort, 1951, fig. 3, a, h) are taken from Giesbrecht's illustrations. Esterly (1905, fig. 3, a, b) and Brodsky (1950, fig. 24) provided additional original figures. Since the appendages of *C. tenuicornis* are identical with those of the new species (Figs. 1, 2) in all details of segmentation and armature, its has not been deemed necessary to illustrate them here.

A complete synonomy for *C. tenuicornis* is given by Verwoort (1946: 22) and need not be repeated. Additional references to this species are those of Mori (1937: 16, pl. 3, figs. 9, 10, pl. 4, figs. 1–3), Wilson (1942: 195; 1950: 269) Brodsky (1950: 95–97, fig. 24), Farran and Verwoort (1951: 3, fig. 3a, 3h), Rose and Vaissiere (1952: 116), and Yamazi (1953: 198).

C. tenuicornis may be distinguished easily from other previously known species of *Calanus* by the elongate first antennae and the reduced size of the outermost setae of the furcae. Elongate first antennae are also characteristic of *C. gracilis* Dana and *C. robustior* Giesbrecht, but both these species differ from *C. tenuicornis* in having a strong hooked spine on the anterior aspect of the second basis of the first swimming legs. Furthermore *C. tenuicornis* is much smaller than the other species (*tenuicornis*, 1.5–2.4 mm.; *gracilis*, 2.3–3.3 mm.; *robustior*, 3.0–3.8 mm.). In both *C. gracilis* and *C. robustior* the long setae on the

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posterior margins of segments 23 and 24 of the first antennae are distinctly segmented even in the early copepodite stages; in *C. tenuicornis* there is no trace of segmentation. Finally, in the two larger species, the proximal part of the outer margin of the third exopodal segment of the second to fourth swimming legs of the male is serrate; in *C. tenuicornis* these margins are smooth.

Sars (1925: 7) erected a new genus, *Neocalanus*, which he did not define, to include *tenuicornis*, *gracilis*, and *robustior*. Although modern authors differ as to the validity of *Neocalanus*, almost all are agreed that *tenuicornis* should not be placed in it. *Neocalanus* was first defined by Verwoort (1946: 39); his definition, which includes the hooked spine of the first swimming legs and the serrations on the second to fourth swimming legs, definitely excludes *tenuicornis*.

C. tenuicornis is widely distributed in tropical and temperate waters, although it is not ordinarily taken in very large numbers. Verwoort (1946) has summarized distribution records from the literature. It is sparingly distributed throughout the Atlantic from about 52° N. to 20° S., with northern record from the Faroe Banks. It is found in all parts of the Mediterranean. In the Indo-Pacific it ranges from about 42° N. to 52° S. Wilson's (1942) records, not mentioned by Verwoort, show it to be widespread in the Eastern Pacific, within about the same latitudinal boundaries. It is not usually a common species in the East Indies. Cleve (1904) records it from both east and west of South Africa. Ordinarily it is an epiplanktonic form.

Calanus lighti new species
Figs. 1, 2

This species is named in honor of the late S. F. Light of the University of California, Berkeley.

ADULT FEMALE: Length, excluding furcal setae, 2.32–3.08 mm. Body form similar to *C. tenuicornis*, but longer and more slender in appearance. Ratio of length to depth of cephalothorax about 6:1 as opposed to 4.5:1 in *C. tenuicornis*. Head with more flattened dorsal slope (lateral view) than in *tenuicornis*. Head separated from first thoracic somite by weakly developed suture. Posterior border of head raised into a small, slightly backward-curved process in dorsal midline. Thorax about one fourth longer than head; second and fourth somites each with two pairs of setae on either side of median dorsal line, anterior pair longer; third somite with two pairs of equal-sized dorso-lateral setae; fifth somite rounded posteriorly, slightly overlapping genital somite. Genital somite produced into somewhat flattened hump ventrally, less produced than in *tenuicornis*. Abdominal somites much longer in proportion to their depth than in *tenuicornis*; somite 2 about one third longer than somite 3 (only one fourth longer in *tenuicornis*). Furcae about 2.5 times as long as wide; the four apical setae very long, especially the next to innermost one, which is about twice as long as the others; lateral setae very short.

First antennae more than twice as long as body; segments 3, 7, 14, 18, 21, and 24 bear elongate setae anteriorly; segments 23 and 24 each bear a very long feathered seta on the posterior surface.

Setae of mouth parts, especially those of the terminal segments, very long. Setae of exopod of first maxilla very long, feathered, and pigmented.

First swimming leg with triangular projection on proximal part of posterior surface of first segment of exopod. Posterior part of distal margin of first segment of endopod produced into a number of minute linear processes in the specimen drawn, not in other specimens examined. Medial margin of first basipod of fifth swimming leg smooth, without setae.

ADULT MALE: Length, excluding furcal setae, 1.90–2.68 mm. Body a little shorter and less slender than in female. Head more rounded in lateral view. Third thoracic somite with two pairs, fourth somite with one pair

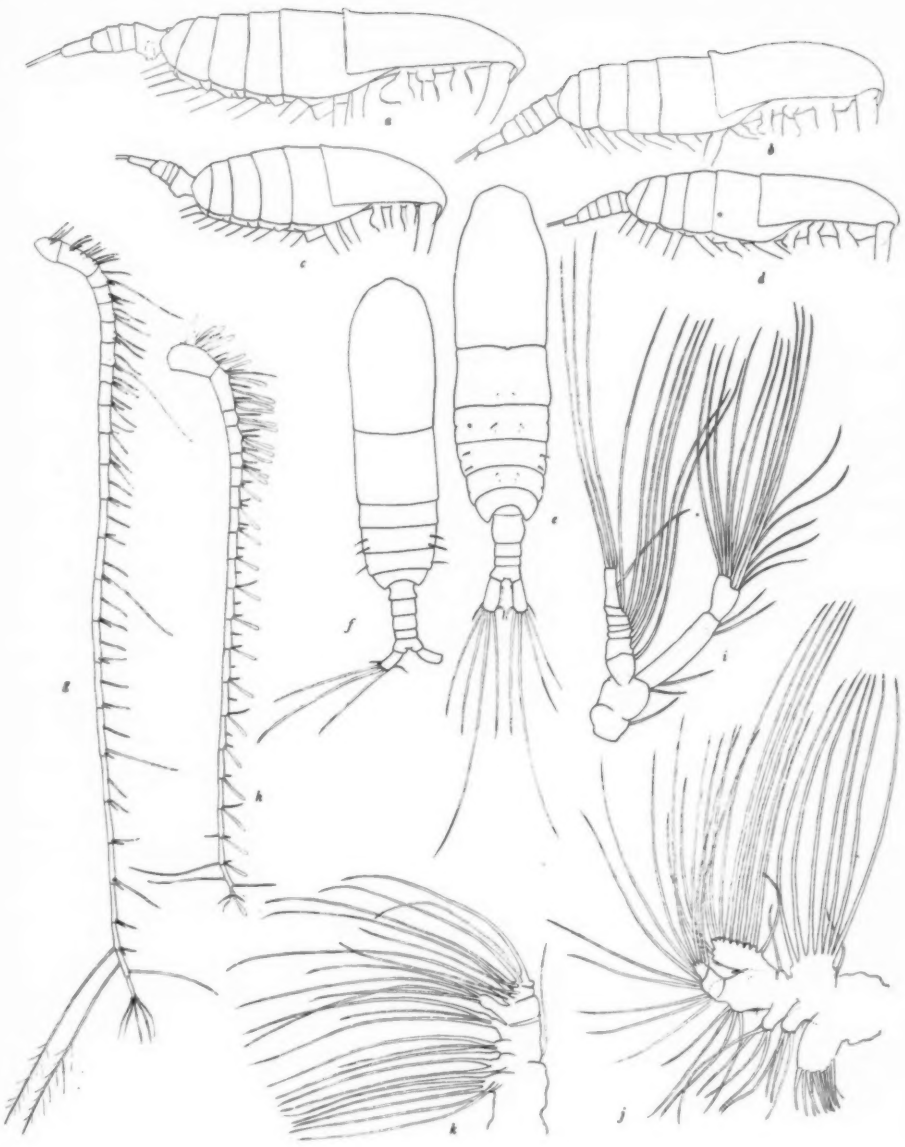

FIG. 1. *a–b, e–k, Calanus lighti* n. sp.; *c–d, Calanus tenuicornis* Dana. *a*, Female, lateral view; *b*, male, lateral view; *c*, female, lateral view; *d*, male, lateral view; *e*, female, dorsal view; *f*, male, dorsal view; *g*, first antenna, female; *h*, first antenna, male; *i*, second antenna, female; *j*, first maxilla, female; *k*, second maxilla, female.

of dorso-lateral setae, larger than those of the female. Furcae usually widely divergent.

First antennae about 1.5 times as long as body; segments 1–2, 3–5, 7–8, and 24–25 fused.

Mouth parts reduced, some of setae reduced in size or absent. Second antennae without setae on proximal segment of endopod. Gnathal lobe of mandible much smaller and more weakly chitinized than in female; teeth only slightly developed; terminal segment of endopod with only nine setae. First maxilla thinly chitinized in comparison with that of female; spines on gnathal lobe reduced.

Fifth swimming legs as in *C. tenuicornis;* no setae on inner margins of exopods; distal segment of left exopod pyriform, with slender terminal spine.

TYPES: The types, all from CCOFI cruises, have been deposited in the United States National Museum. They are listed in Table 1.

Over 100 specimens of *C. tenuicornis* from CCOFI cruises have been added to the United States National Museum collections.

Eight paratypes of *C. lighti* and 11 specimens of *C. tenuicornis* have been deposited at the Scripps Institution of Oceanography, La Jolla, California. Seven paratypes of *C. lighti* and 18 specimens of *C. tenuicornis* have been sent to the Allan Hancock Foundation, University of Southern California.

REMARKS: *C. lighti* is most readily distinguished from *C. tenuicornis* by the shape of the body in lateral view. In addition to the generally more slender and elongate form, the new species is characterized by the more pronounced dorsal elevation at the posterior margin of the head and the ratio of length to depth of the abdominal somites. The males of the two species are less easily distinguished than the females. Where the two species occur together the differences in size and form are readily discernible in both sexes. If only one species is present, it can be assumed that the males are conspecific with the usually much more numerous females.

The posterior process on the first segment of the exopod of the first swimming leg (Fig. 2f) apparently has not been recorded previously from calanoid copepods, probably because of its inconspicuousness. It is, however, not limited to the species treated in this paper, for I have observed a similar, less pronounced process in *Calanus gracilis*, *C. robustior*, *C. finmarchicus*, and *Undinula vulgaris* but not in *Calanus minor*. Possibly it is of rather widespread occurrence. A somewhat similar process on the posterior aspect of the second basal segment of the first swimming leg is reported by Sewell (1947: 165, text fig. 49) for members of the family Metridiidae.

Without exception, the furcae in all the specimens of *C. tenuicornis* and *C. lighti* that I have examined contained a number of

TABLE 1

DATA ON TYPES OF *Calanus lighti* SP. NOV.

	CRUISE	STATION			USNM NO.
Holotype ♀, 1	5	1008	28° 50′ N	121° 19′ W	97109
Allotype ♂, 1	5	1008	28 50	121 19	97110
Paratypes, 16	5	1008	28 50	121 19	97111
66	6	807	32 05	124 55	97112
20	9	1204	26 16	117 03	97113
88	9	1009	28 31	121 52	97114
3	4	1105	28 04	118 36	97115
5	20	120.110	25 33	119 44	97116
50	9	1011	27 56	122 59	97117

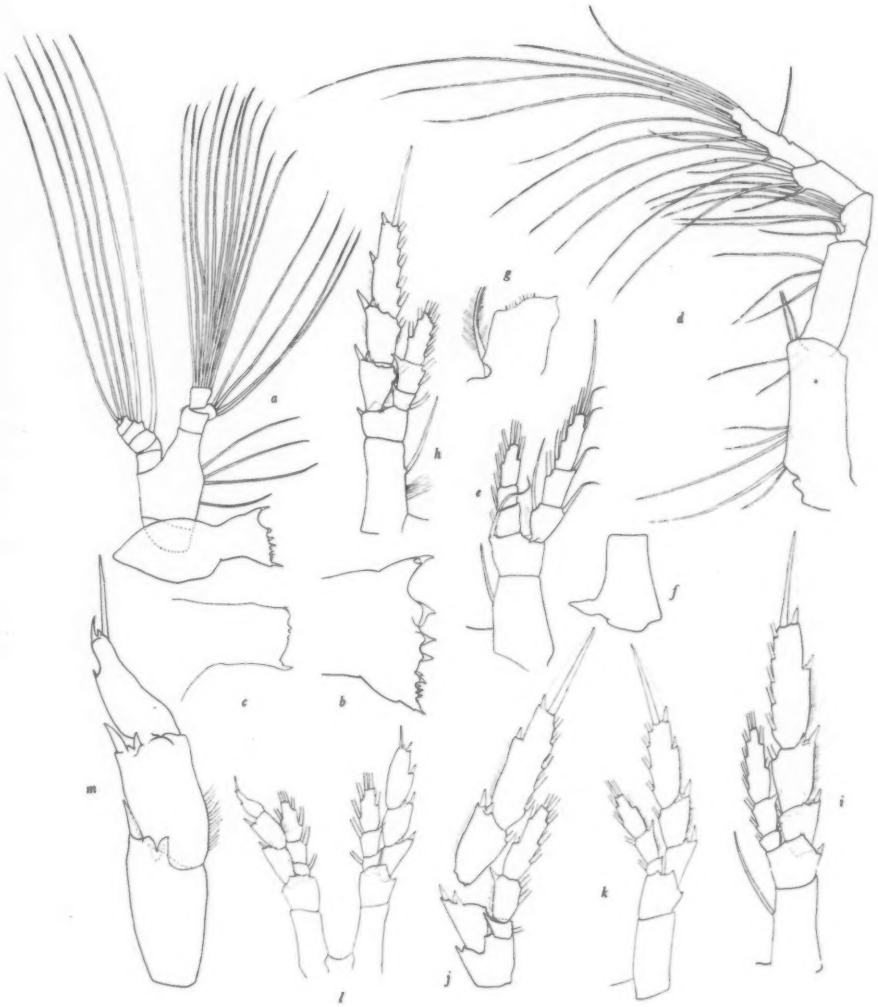

FIG. 2. *Calanus lighti* n. sp. *a*, Mandible, female; *b*, gnathal lobe of mandible, female; *c*, gnathal lobe of mandible, male; *d*, maxilliped, female; *e*, first leg, female; *f*, first segment of exopod of first leg, female, lateral view; *g*, first segment of endopod of first leg, female; *h*, second leg, female; *i*, third leg, female; *j*, fourth leg, female, first basipod not shown, distal part of exopod separated from first segment; *k*, fifth leg, female; *l*, fifth leg, male; *m*, exopod of left fifth leg, male.

TABLE 2

LENGTH OF THE CEPHALOTHORAX IN *Calanus tenuicornis* AND *C. lighti*
(Measurements in Millimeters)

STATION	*Calanus tenuicornis* DANA			*Calanus lighti*, SP. NOV.		
	Number of specimens	Average	Range	Number of specimens	Average	Range
Cruise 6						
107	5	1.54	1.49–1.59			
205	13	1.54	1.47–1.59			
405	15	1.66	1.54–1.81			
605	17	1.78	1.64–1.88			
707	12	1.66	1.47–1.76			
807	13	1.54	1.40–1.81	45	2.31	2.17–2.41
1011				11	2.05	1.88–2.31
1107	8	1.57	1.52–1.61	15	2.02	1.88–2.12
1201	27	1.74	1.64–1.88			
1205	14	1.64	1.54–1.71	100	2.07	1.90–2.27
Cruise 9						
1009	28	1.54	1.37–1.61	90	2.01	1.83–2.14

spherical refractile bodies. These represent a protozoan parasite which is probably responsible for the erosion of the furcal setae noticed in all specimens examined. It has been practically impossible to find specimens with all the furcal setae intact, and I have not found a single male with an undamaged next-to-outermost seta. These parasites are so characteristic that they can almost be used for separating these two species from other planktonic copepods.

SIZE RELATIONSHIPS

The body length of *C. tenuicornis* is given by several investigators (Dana, 1853; Giesbrecht, 1892; Esterly, 1905; Farran, 1929; Rose, 1933; Verwoort, 1946). Comparative measurements of the body lengths of *C. tenuicornis* and *C. lighti* are:

	FEMALE *mm.*	MALE *mm.*
C. tenuicornis, from literature	1.8 –2.1	1.5 –1.95
C. tenuicornis, CCOFI specimens	1.64–2.39	1.71–2.02
C. lighti, CCOFI specimens	2.32–3.08	1.90–2.68

In Table 2 are given the cephalothorax lengths of 413 specimens of *C. tenuicornis* and *C. lighti*, mostly from CCOFI Cruise 6 (August, 1949), with one station from Cruise 9 (November, 1949). It is noteworthy that at the five stations where both species were taken there was no overlap in size at any one station. The absence of intermediate forms is evidence that interbreeding between the two copepods does not occur.

DISTRIBUTION IN THE NORTHEAST PACIFIC

Figure 3 shows the distribution of the *Calanus tenuicornis* and *C. lighti* encountered during four CCOFI cruises. At the stations shown, oblique hauls of 20 minutes duration were made with one meter plankton nets from a depth of about 70 meters (140 meters in Cruise 20) to the surface. Details of net construction and methods by which the hauls were made are given by Ahlstrom (1948, 1952). *C. tenuicornis* was widely distributed over the area covered, while *C. lighti* was limited to the stations south of Point Conception. It is interesting to note that *C. lighti* extends furthest north at the outermost stations, so that the northern boundary of its range roughly parallels the surface isotherms. This sort of distribution is very common among certain planktonts in this region and

has been observed (unpublished) by students of several different groups who are working on the collections of these cruises. We do not have here a case of a northern form being replaced to the south by a southern form, but apparently of a widely distributed species (*C. tenuicornis*) and a species with restricted distribution (*C. lighti*). Figure 4 shows the stations occupied during a cruise made by CCOFI in cooperation with the Inter-American Tropical Tuna Commission. No counts were made of the copepods taken at these

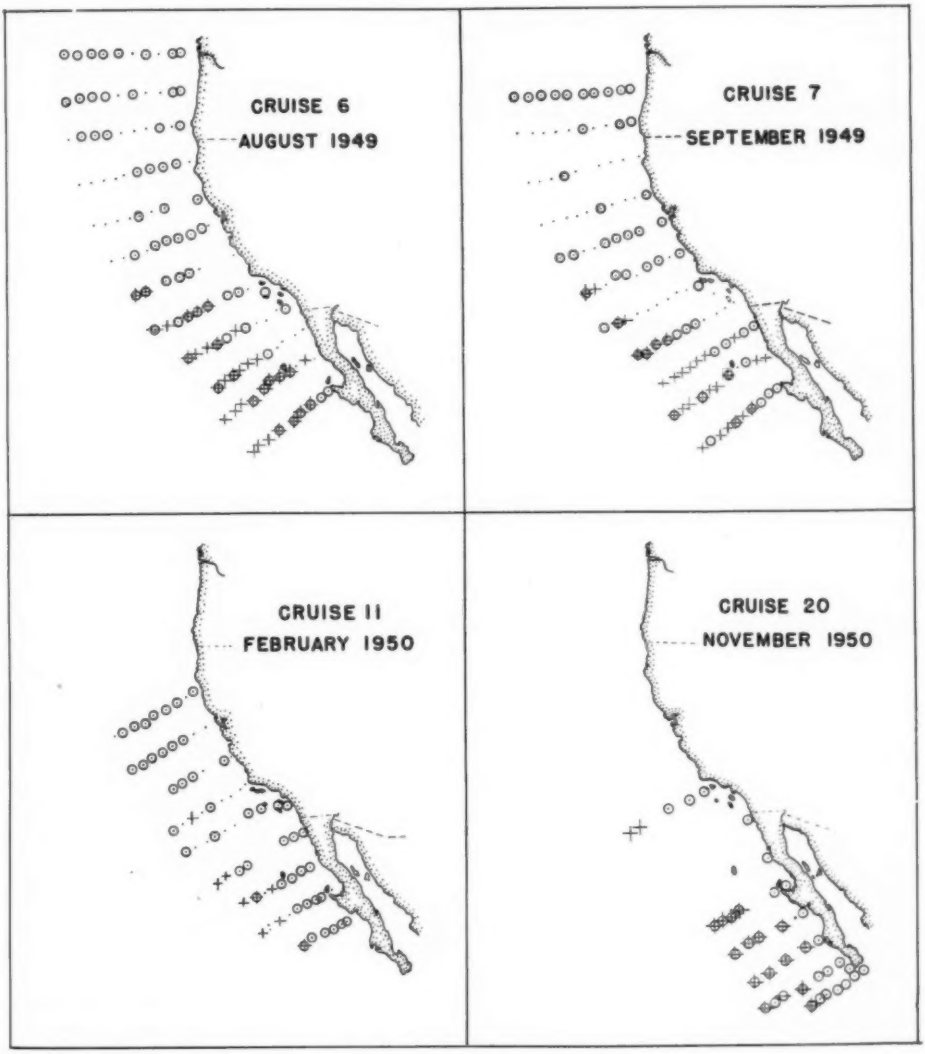

FIG. 3. Distribution of *Calanus tenuicornis* and *C. lighti*, from four CCOFI cruises. Dots, stations occupied; circles, *C. tenuicornis;* plus marks, *C. lighti.*

stations, but they were examined to see whether either *C. tenuicornis* or *C. lighti* was present. In all samples examined *C. tenuicornis* was present, but no specimens of *C. lighti* were found. *C. lighti* appears to be limited to oceanic waters off the coasts of southern California and Baja California, while *C. tenuicornis* occurs in neritic as well as oceanic waters, and has a much greater north-south range. Further information is needed concerning the distribution of *C. lighti* to the west of the area from which I have examined plankton samples.

The type specimen of *C. tenuicornis*, unfortunately no longer extant, was taken at 40° N., 157° W. To assist in determining which of the two forms from the CCOFI cruises was Dana's species, some of the plankton samples from stations of the "Northern Holiday" cruise of the Scripps Institution of Oceanography in 1951 were examined. At the following stations only the smaller form (*C. tenuicornis*) was taken; no *C. lighti* was found in the sample:

"NORTHERN HOLIDAY" STATION	LATITUDE	LONGITUDE
45	42° 15′	155° 36′
46	41° 20′	155° 20′
47	40° 09′	155° 03′
48	39° 18′	154° 38′
49	38° 30′	154° 25′
50	37° 28′	154° 12′
56	28° 06.5′	151° 25′

This makes it highly probable that the smaller form is conspecific with Dana's specimen. The more restricted range of the larger form (*C. lighti*), which appears to be limited to an area not yet thoroughly explored, perhaps explains why it has not been discovered previously.

DISCUSSION

It might be argued that since the two forms discussed herein differ only in body size and conformation they do not merit specific distinction. However, the available evidence indicates that they must be treated as different

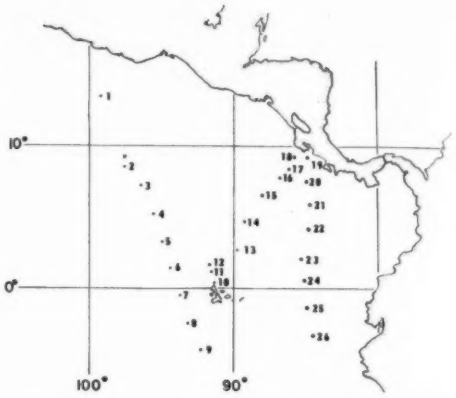

FIG. 4. Station positions of the CCOFI-Inter-American Tropical Tuna Commission Cruise, January 1–March 4, 1953 in the east-central Pacific. *Calanus tenuicornis* was present in all stations; *C. lighti* was found at none.

species, rather than as subspecies or environmentally determined forms of a single species.

1. Although the geographic range of *tenuicornis* overlaps extensively the more restricted range of *lighti*, each species is characterized by a distinct geographic range.

2. The absence of specimens intermediate in size or in body form at stations where the two species occurred together is evidence that the two copepods are reproductively isolated.

3. The two species differ in their pigmentation. Preserved females of *C. lighti* have spherical spots of red pigment in the first antennae. These were not found in any preserved female of *C. tenuicornis*, or in five living specimens brought to the laboratory from about three miles off Point Loma, California.

It is possible that the two forms will be found to intergrade in other regions where their ranges overlap. Such a discovery might make it necessary to reduce *C. lighti* to subspecific rank. For the present, however, it is given specific status.

It is well known that the size and form of both marine and fresh-water copepods can be modified by environmental influences, especially temperature. When reared in the lab-

oratory at low temperatures, fresh-water copepods (*Cyclops*) tend to reach a larger size (Coker, 1933) and to have longer and narrower furcae (Coker, 1934). Steuer (1925, 1931, 1932) has erected "forma" and geographic races for several species of marine copepods; the larger forms were from the colder parts of the geographic range or from deeper, hence colder water. Recently, Deevey (1952) reviewed the subject of seasonal variations in size in marine copepods; her own studies showed an inverse correlation between temperature and size in *Centropages typicus* and *C. hamatus*.

Because of these findings, it is necessary to consider the possibility that the two forms of *Calanus* (*tenuicornis* and *lighti*) are actually ecophenotypes. If such were the case we would expect to find the largest specimens in the coldest water, with a gradual and more or less continuous decrease in size to the south. Instead of this, it has been pointed out that the smaller, more chunky form occurs in both colder and warmer water than the longer, more slender *C. lighti*. Hence it is clear that the two species are not temperature-induced ecophenotypes.

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The Land Mollusca of the Treasury Islands, Solomon Islands

R. K. DELL[1]

IN THE COURSE of war service in the Solomon Islands the writer was stationed on Stirling Island in the Treasuries from December 10, 1943, to January 13, 1944. A collection of land snails was made and subsequently this was supplemented by a collection made on Mono Island at about the same time by Mr. N. Gardner. Smith (1885) recorded a number of species collected by Guppy from the group, but since that time little has been added. A great deal of scattered work has been published on the land snails of the Solomons but few faunal lists have been prepared for any specific island or group. The writer has recently (Dell, 1955) given an account of the land snails of an island in the northern Solomons (Nissan) and the present account presents another step towards a fuller understanding of the zoogeography of the Solomon Islands.

The Treasury Group consists of two main islands, Mono and Stirling. Mono is a compound volcanic and coral deposit island some five and one half by nine miles in extent rising to 1,150 feet. Stirling, slightly to the south, is an elevated barrier reef with a comparatively flat surface rising to no more than 71 feet (Guppy, 1887). Most of the surface of both islands was clothed in thick tropical vegetation.

The following account is not complete as the exigencies of military service did not allow for comprehensive collecting and smaller species undoubtedly were missed. Smith's records have been incorporated. The writer is deeply indebted to Mr. N. Gardner who freely made the results of his collecting available and has presented specimens of a number of new species to the Dominion Museum.

[1] Dominion Museum, Wellington, New Zealand.
Manuscript received October 9, 1954.

LIST OF SPECIES

Leptopoma vitreum (Lesson, 1830), Stirling
Pupina solomonensis Smith, 1885, Mono
Diplommatina aerari n. sp., Mono
Diplommatina solomonensis n. sp., Mono
Palaina gardneri n. sp., Mono
Sturanya modesta (Pfeiffer, 1853), Mono, Stirling
Sturanya solomonensis (Smith, 1885)
Geophorus agglutinans (Sowerby, 1843), Stirling
Palaeohelicina egregia (Pfeiffer, 1885), Stirling
Pseudocyclotus levis levis (Pfeiffer, 1885), Mono
Omphalotropis nebulosa Pease, 1872, Mono
Papusuccinea simplex (Pfeiffer, 1885), Mono
Orpiella (*Owaraha*) *treasuryensis* (Tryon, 1886), Mono
Dendrotrochus cineraceus cineraceus (H. & J., 1841), Mono, Stirling
Sheba hombroni (Pfeiffer, 1856), Mono, Stirling
Papuina cf. *gamelia* (Angas, 1867), Mono, Stirling
Partula sp., Mono
Placostylus (*Placocharis*) *founaki* H. & J. 1854, Mono
Opeas gracile (Hutton, 1834), Mono

Leptopoma vitreum Lesson, 1830

This species was comparatively common on vegetation on Stirling Island. It has been recorded elsewhere in the area from Guadalcanar, Malaita and Santa Anna (Rensch, 1936), Shortland Islands and Simbo (Smith, 1885), Bismarck Archipelago (Rensch, 1937), Nissan Island (Dell, 1955), and the writer has specimens from Savo Island, coll. R. R. Foster, –4–1944.

Pupina solomonensis E. A. Smith, 1885

Smith in his original description recorded this species from Treasury Island, but it does not appear to have been collected since from that locality. Species of this genus are, however, often local and may be overlooked easily. The distinction between this species and *P. keraudreni* Vignard appears to be slight, and the two forms have a similar range throughout the Solomon Islands.

Palaina gardneri n. sp.

Fig. 1*c*, *d*

Shell small, dextral, turretted, light brown in colour, but generally stained. First one and a half whorls with numerous fine axials. Subsequent whorls with numerous thin, raised, rather oblique lamellae which are more widely spaced on the body whorl (24 on penultimate).

Whorls six and a half, the first one and a half whorls mammillate, the following whorls gradually increasing, resulting in a turretted outline. Suture impressed, periphery rounded. A constriction in the shell of the body whorl above the aperture, the axials much finer and closer in the constriction. Aperture rounded, toothless, peristome continuous, the parietal portion compressed against the body whorl, margin thickened, expanded.

Height, 4.64 mm.; diameter, 2.27 mm., height of aperture, 1.64 mm.

HOLOTYPE: (M. F. 2516) and paratype (M. F. 2517) in Dominion Museum, Wellington. Two paratypes in the collection of Mr. N. Gardner, Auckland, New Zealand. All specimens collected by N. Gardner, 1944.

LOCALITY: In leaf mould from ridge above Seveke River, Mono Island, Treasury Group.

This appears to be the first species of the genus to be recorded from the Solomon Islands, although it is known from many of the surrounding island groups, e.g., Bismarck Archipelago (Rensch, 1937), New Hebrides (Ancey, 1905), New Caledonia and Lord Howe Island. The turretted outline distinguishes this species from any of the geographically neighbouring forms.

The species is named for Mr. N. Gardner who collected the type series and generously donated this and other material to the Dominion Museum.

Iredale (1944: 303) has discussed the question of the type species of *Palaina* and shown that it must be one or other of the only two identifiable species listed originally by Semper. Of these two species Iredale has selected *macgillivrayi* Pfeiffer from Lord Howe Island as type.

Diplommatina aerari n. sp.

Fig. 1*b*

Shell small, sinistral, spindle shaped, light brown. Whorls five and a half, apical whorls worn but first one and a half whorls apparently smooth. Following whorls with numerous raised, somewhat oblique lamellae, becoming more widely spaced on body whorl. Interstices with fine growth lines. The first one and a half whorls are mammilate, following three rapidly increasing, body whorl somewhat restricted. The major part of the body whorl above the aperture considerably depressed. The axials finer and more numerous in the depression. Body whorl rather angled at each side of the depression. Suture impressed. Aperture rather oblique, peristome continuous, subcircular, almost fused to the body whorl at the depression. A rather weak tooth in the centre of the peristome on the columellar side. Margin thickened, slightly channelled.

Height, 3.91 mm.; diameter, 2.18 mm.; height of aperture, 1.64 mm.

HOLOTYPE: (M. F. 2514) in Dominion Museum, Wellington. Collected by N. Gardner, 1944.

LOCALITY: In leaf mould from ridge above Seveke River, Mono Island, Treasury Group.

This and the following species are apparently the first records of the genus from the Solomon Islands. Species of *Diplommatina* have not as yet been recorded from the Bismarck Archipelago. The genus is probably quite widely distributed in both groups, but smaller land snails have undoubtedly been neglected in both groups. Thorough conchological exploration, especially of the larger islands, would certainly yield a rich harvest.

Diplommatina aerari bears a striking resemblance to *Palaina commixta* Rensch from New Britain but differs of course in the possession of the columellar tooth and in the outline of the aperture.

Diplommatina solomonensis n. sp.
Fig. 1*a*

Shell small, dextral, subcylindrical but upper whorls gradually tapering to a widely rounded apex, pale yellowish brown. Whorls six and a half, regularly increasing to about the fourth whorl, suture impressed. The last two whorls approximately the same width. The first one and a half whorls sculptured with very fine axials, followed on subsequent whorls by fairly regular, numerous, raised lamellae, microscopic spirals between the lamellae. Body whorls flattened in the middle above the aperture.

Aperture rounded, entire, flared outwards, closely appressed to body whorl at the flattened portion. A small, but prominent, tooth on the columella side of the peristome. Peristome margin wide, slightly channelled. The region behind the peristome on the body whorl considerably thickened, the thickened portion clearly marked off by a prominent raised axial rib.

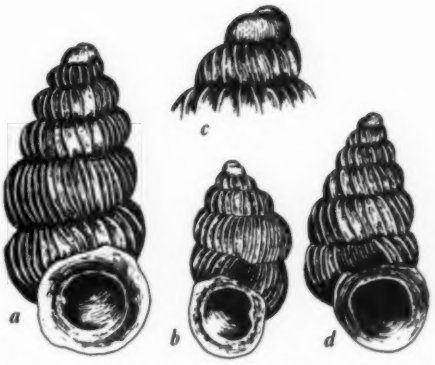

FIG. 1. *a*, *Diplommatina solomonensis* n. sp., holotype (3.09 × 1.45 mm.); *b*, *Diplommatina aerari* n. sp., holotype (3.91 × 2.18 mm.); *c*, *Palaina gardneri* n. sp., protoconch; *d*, *Palaina gardneri* n. sp., holotype (4.64 × 2.27 mm.).

Height, 3.09 mm.; diameter, 1.45 mm.; height of aperture, 1.18 mm.

HOLOTYPE: (M. F. 2515) in Dominion Museum, Wellington. Collected by N. Gardner, 1944.

LOCALITY: In leaf mould from ridge above Seveke River, Mono Island, Treasury Group.

Diplommatina solomonensis n. sp. differs at sight from *D. aerari* in being dextral, in having a much narrower shell, and a very different spire outline.

The remaining 14 species are members of the family Helicinidae. The forms of this family from the Solomons and indeed from the Pacific islands generally are urgently in need of revision. Wagner's works on the genus are not available in this country but the figures and descriptions that have been published are usually totally inadequate for the fine discrimination of species. Figures such as those of Reeve are too small and indefinite. The systematics of the group is a problem that can be solved only by those having access to the type specimens and to adequate, carefully localized series of specimens. The following species have been recorded from the Treasury Group but the identifications should be taken as provisional only.

Sturanya modesta (Pfeiffer, 1853)

This species was recorded from the Treasury Group by Smith (1885) and there are specimens in the Suter Collection of land shells (now in the Dominion Museum), sent to Suter by Hedley from the same locality. A small yellow helicinid was common in vegetation on Stirling Island but, unfortunately, the specimens collected by the writer were lost in transit.

Sturanya solomonensis (Smith, 1885)

Specimens from Treasury Island were recorded by Smith in his original description of the species. Rensch (1936: 682) indicated that this species probably was synonymous with *modesta* (Pfr.).

Geophorus agglutinans (Sowerby, 1843)

The writer collected a single specimen from Stirling Island which is close to, if not identical with, this species. There are also similar specimens in the Suter Collection (ex Beddome) from "Treasury Islands."

Palaeohelicina egregia (Pfeiffer, 1853)

Specimens which are referable to this species were collected by N. Gardner from Stirling Island.

Pseudocyclotus levis levis (Pfeiffer, 1855)

N. Gardner collected this species from Mono Island. From the Solomon Group it has been recorded from Bougainville, Faro, Shortland Island, Choiseul, New Georgia, Guadalcanar, Santa Anna (Rensch, 1936); Nissan (Dell, 1955); and is known to the writer from Galera (Suter Collection) and from Savo, collected by R. R. Foster. –4–1944.

Omphalotropis nebulosa Pease, 1872

This species also was collected from near the Seveke River, Mono Island by N. Gardner.

Papusuccinea simplex (Pfeiffer, 1854)

The species was recorded from Treasury by Smith (1885).

Iredale introduced his new genus *Papusuccinea* for the New Guinea form, which he regarded as distinct from the widespread *Succinea simplex* Pfeiffer originally described from "Solomon's Islands" (not the New Hebrides as stated by Iredale), without giving any concrete differences between it and related forms. The genus may well be used until anatomical investigation determines its validity.

Orpiella (Owaraha) treasuryensis (Tryon, 1886)

1885 *Helix* (*Nanina*) *nitidissima* Smith, *Zool. Soc. London, Proc.* 1885: 589, pl. 36., fig. 1.

1886 *Nanina* (*Eurypus*) *Treasuryensis* Tryon, *Man. Conch.* (2) 2: 111, pl. 37, f. 100, 1, 2. (New name for *nitidissima* Smith, 1885, now Moellendorff.)

1923 *Fretum treasuryensis* (Tryon); Clapp, *Harvard Univ., Mus. Compar. Zool., Bul.* 65: 357.

1936 *Orpiella treasuryensis* (Tryon); I. Rensch and B. Rensch, *Rev. Suisse de Zool.* 43 (32): 657.

Originally, this species was described from Treasury but does not appear to have been collected there since. Rensch (1936: 657) records it also from Guadalcanar.

Genus DENDROTROCHUS Pilsbry, 1894

Orthotype: *Helix heliconoides*, H. & J. (= *Helix* (*Geotrochus*) *cleryi simboana* Smith).

Baker (1941: 256) has shown that *heliconoides* (Jacquinot) Pfeiffer must be considered to be preoccupied by Mousson. The first valid name for this species appears to be *Helix* (*Geotrochus*) *cleryi simboana* Smith. Rensch (1924) has considered a number of the species of *Dendrotrochus* from the Solomons and the Bismarck Archipelago to form a "Rassenkreis" and has utilized *heliconoides* as the nominate form using *cineraceus* (H. & J.) in a subspecific sense. *Helix heliconoides* H. &

J. dates from 1849 and *Helix cineraceus* (H. & J.) from 1841, so that *cineraceus* as the oldest valid name, should have been used as the nominate form. The available names for the Solomon Island members of the "Rassenkreis" that Rensch considered would be as follows:

Dendrotrochus cineraceus cineraceus (H. & J., 1841)
Choiseul and Shortland Island (Rensch), (Hombron and Jacquinot gave New Guinea).

Dendrotrochus cineraceus cleryi (Recluz, 1851)
Solomon Islands.

Dendrotrochus cineraceus meridionalis (Smith, 1885)
Santa Anna.

Dendrotrochus cineraceus simboana (Smith, 1885)
Simbo.

Dendrotrochus cineraceus septentrionalis (Smith, 1885)
Choiseul Bay, Shortland, Treasury Islands.

Dendrotrochus cineraceus cyrene (Crosse)
Ugi.

Dendrotrochus cineraceus tenera (I. and B. Rensch, 1935)
Guadalcanar, Savo, Ysabel.

The type locality of *cineraceus* is in some doubt but from the original figure Rensch seems to have placed it fairly satisfactorily in the Bougainville Strait area. Smith's *septentrionalis* would then be an exact synonym of *cineraceus* and in Rensch's opinion, *simboana* Smith should be treated as equivalent to *heliconoides*. Rensch also considers that *cyrene* Crosse and *meridionalis* Smith are synonyms of *cleryi* Richy. Accepting these conclusions the following subspecies should be recognized:

Dendrotrochus cineraceus cineraceus (H. & J. 1841)
Choiseul, Shortland, Treasury.

Dendrotrochus cineraceus simboana (Smith, 1885)
Simbo, Hammond, Ysabel, Guadalcanar, Malaita, Vella Lavella (Dominion Museum).

Dendrotrochus cineraceus cleryi (Recluz, 1851)
San Cristobal, Santa Anna, Ugi, Ulawa, Bio.

Dendrotrochus cineraceus tenera (I. and B. Rensch, 1935)
Guadalcanar (Savo specimens are intermediate between *tenera* and *simboana*).

This grouping is essentially that of Rensch, although at first sight the nomenclature appears very different.

Dendrotrochus cineraceus cineraceus (H. & J., 1841)

A single specimen from Stirling Island, collected by N. Gardner is referable to this form. As already noted, Smith (1885) recorded this form from the Treasuries as *cleryi simboana*.

Sheba hombroni (Pfeiffer, 1856)

A specimen was collected by the writer from Mono Island and two from Stirling Island by N. Gardner. There are other specimens in the Dominion Museum from the group (Suter Collection) and one from Shortland Island.

Papuina (Solmopina) aff. gamelia Angas, 1867

Three specimens of a *Papuina* have been seen by the writer from the group, one from Stirling and two from Mono. The species centred round *gamelia* and *hargreavesi* Angas have not been clearly defined. *P. gamelia* was described from St. Stephen and Ysabel. Smith (1885) added Shortland, Treasury and Choiseul. Rensch (1935) made *hargreavesi* Angas a synonym and added Bougainville to the list of localities. It is unfortunate that Rensch did not figure any of the large series he had from Choiseul (170 shells). The Treasury shells that the writer has seen do not agree with the figures of *gamelia* given by Angas in Tryon, being comparatively shorter. Nor do they agree with shells from Bougainville. Until this group of *Papuina* from around Bougainville Strait can be accurately defined there can be no finality in the matter.

The Treasury shells have the following dimensions: Height, 14.8, 17.4, and 15.0 mm.; diameter, 20.5, 21.8 and 21.2 mm., respectively. All three specimens have a comparatively sharp angulation on the periphery of the body whorl. The development of the dark brown spiral bands varies somewhat. A faint suprasutural band develops on the penultimate whorl to continue across the body whorl as a thin band above the periphery, and a stronger spiral band encircles the body whorl below the periphery. The columella is white tinged with faint pinkish purple.

Genus PARTULA Férussac, 1821

Subgenus MELANESICA Pilsbry, 1909

Clench (1941: 19) supplied a résumé of progress in knowledge of the Solomon Islands members of the group, and commented that there was little to report subsequent to Pilsbry's review of the group in 1909. Identifications of Solomon Island material using the literature available has proved to be impossible and it is obvious that a critical review of the group based upon the type material and ample localized series is long overdue.

Partula (Melanesica) cf. **cinerea** Albers
Fig. 2

A single specimen has been seen from the Treasury Islands which could be identified from the literature with any one of a number of forms. It is figured here for the benefit of a future monographer. The other available Solomon Island material will be described later.

Smith (1885: 955) identified specimens from Treasury Island collected by Guppy as *P. cinerea* Albers and also recorded the same species from Gulph Island (coll. Brenchley) and Guadalcanar (coll. Macgillivray). Sowerby and Fulton recorded *micans* Pfeiffer from the nearby Shortland Islands (*fide* Pilsbry, 1909: 295). Clench (1941: 20) synonymises both *cinerea* Albers and *perlucens* Hartman with

FIG. 2. *Partula* (*Melanesica*) cf. *cinerea* Albers. Treasury Islands (12.7 × 7.3 mm.).

micans Pfeiffer and indicates that the record by Sowerby and Fulton probably is based on another species. *M. micans* apparently occurs on a group of islands around Ugi, San Cristoval.

The single Treasury specimen of four and a half whorls is considerably smaller than any specimens seen from Guadalcanar. Height, 12.7 mm.; diameter, 7.3 mm.; height of aperture, 6.4 mm., width of aperture, 4.5 mm.

Placostylus (Placocharis) founaki
(Hombron and Jaquinot) Rousseau, 1854

A number of specimens were collected at Falimai, Mono Island, by N. Gardner. Clench (1941: 8) has recently summarized our knowledge of the species which has been recorded from a number of localities about Bougainville Strait (Bougainville, Choiseul, Faro, and Treasury) and from Ysabel.

Opeas gracilis Hutton, 1854

Specimens of this widely distributed species were collected from near the Seveke River, Mono Island, by N. Gardner.

DISCUSSION

Any discussion of the distribution of the land snails of the Solomons is hampered by our lack of knowledge of the exact distribution of any species within the group. Thus the three species that apparently are endemic to the Treasuries, *Diplommatina aerari*, *D.*

solomonensis, and *Palaina gardneri*, very probably occur elsewhere but have not been collected. Of the 19 species recorded here, the following eight have a wide range of distribution throughout the group: *Papusuccinea simplex*, *Pupina solomonensis*, *Sturanya modesta*, *Palaeohelicina egregia*, *Pseudocyclotus levis*, *Leptopoma vitreum*, *Omphalotropis nebulosa*, and *Opeas gracilis*. Two species, *Orpiella treasuryensis* and *Partula* sp. appear to have affinities with the fauna of the southern Solomons. A significant three species have a distribution restricted to the islands surrounding Bougainville Strait. Thus *Dendrotrochus cineraceus cineraceus* is, as far as is known, confined to Choiseul, Shortland, and Bougainville, whereas *Placostylus founaki* and *Papuina gamelia* both apparently extend to Bougainville and as far south as Ysabel. However, neither of these species reach Vella Lavella, Gizo or New Georgia where the genera are represented by very different species. The land snail relationships appear to extend from Bougainville via Shortland and Treasury, Choiseul and Ysabel, but not via Vella Lavella to New Georgia. This point will be dealt with more fully on a later occasion.

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A Preliminary Phytochemical Survey of Papua-New Guinea

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BOTANICAL EXPLORATION of the island of New Guinea as a whole was not seriously undertaken until about 1875. Then and for some time subsequently, the flora of British New Guinea was less intensively studied than that of Dutch and German New Guinea (White, 1923: 8). It is not surprising, therefore, that, until recently, little attention was paid to the phytochemical resources of what is now known as the Territory of Papua-New Guinea. By contrast, active botanical research including chemistry and pharmacology of tropical plants was undertaken at Bogor (Buitenzorg) beginning in 1888 (Koolhaas, 1945: 207). In addition to limited timber-milling, exploitation of coconut (copra) and sugar cane (for propagation) nearly summarises European interest in the resources of the New Guinea flora.

So far, there has been no commercial development of an indigenous New Guinea plant as a pharmaceutic agent although the native peoples of the Territory, in common with those of other lands, possess hundreds of reputed remedies of plant origin. This empirical information has not been systematically recorded, although noteworthy attempts have been made by some interested missionaries and administration officials. Tropical countries, such as Africa and South America, with rich rain forest floras, have contributed several notable plant drugs to world medicine, e.g., quinine, cocaine, and curare. The failure of New Guinea (as well as Australia) to provide a similar array of useful drugs may be due to its comparatively late contact with modern technology, and to economic factors.

An Australian Phytochemical Survey, begun in the latter part of World War II, revealed many new and potentially valuable alkaloids, saponins, pigments, antibiotics, and other compounds of chemical interest (Webb, 1953). The tropical and subtropical rain forests of eastern Queensland and northern New South Wales yielded proportionately more species with alkaloids than did other plant formations. Their specific diversity, and the large quantities of bark and other material available for analysis from the dominant tree flora, make the rain forests an attractive sample reservoir for organic chemists. Many of the alkaloid-bearing families, such as Rutaceae, Lauraceae, Loganiaceae, Monimiaceae, Menispermaceae, Apocynaceae (Webb, 1952*a*), are characteristic inhabitants of the tropics, and are well represented in New Guinea.

This prompted a recommendation to the Commonwealth Scientific and Industrial Research Organization from the Third Australian Phytochemical Conference held in Sydney in May, 1951, that a brief reconnaissance of New Guinea phytochemical resources and facilities be made, to serve as a basis for a later more intensive survey, e.g., in conjunction with the Land Research and Regional Survey Section

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(C.S.I.R.O.). This recommendation was approved and the writer and Dr. C. Barnard (Division of Plant Industry, C.S.I.R.O.) spent August and September, 1951, in various parts of the Territory of Papua and New Guinea. Lowland areas near Port Moresby, Popondetta, Lae, and Rabaul, and highland areas at Wau, Aiyura, and Nondugl, were selected as representative plant communities, accessible within the brief itinerary planned. Colonel J. K. Murray, then Administrator of the Territory of Papua-New Guinea, and other administration officials were responsible for transport and accommodation arrangements.

Following the stimulus to interested people provided by this trip, and a subsequent appeal (Webb, 1952*b*), several plants reputed to be native remedies were received from New Guinea. Some of these are active pharmacologically and are being examined further. Among these are possible antibiotics and plants reputed to cause temporary sterility in women. Alkaloids in species of Rutaceae and Monimiaceae have been characterized also.

METHODS

The short time in the field was obviously inadequate for systematic collecting and testing. Nevertheless, a fairly wide coverage was obtained of species common in each area. In the field, the procedure was to identify the plant, at least to family level, and if possible to genus. Because of the hurried nature of the trip, no effort was made to collect complete herbarium specimens, although small wood samples were obtained wherever possible. Thus specific identification of relatively few specimens was sacrificed for coverage of a greater number of plants, many of which were identified with certainty at the generic level only. Together with the 300 samples actually collected for spot-testing, and plants tasted or otherwise rejected at sight in the field, over 600 different species of angiosperms were examined, chiefly for alkaloids, during the trip.

Once the botanical affinities of a plant were known, its promise as a source of alkaloids, saponins, etc., could be judged to some extent, on the basis of experience in the Australian Phytochemical Survey. Tasting of bark, seeds, etc. was freely used as a guide (although certain inimical families such as Anacardiaceae were not tested in this way). For example, bitterness in Lauraceae, particularly if a *Cryptocarya*, would suggest alkaloids. Bitterness in Rhamnaceae, on the other hand, indicates that saponins are likely to be present. With practice, alkaloids and saponins may sometimes be differentiated by taste alone. Other field criteria such as colour of inner bark were used in certain cases. Thus, vivid yellow inner bark in *Evodia*, *Acronychia* or *Melicope* (Rutaceae) supplements the evidence of bitterness that alkaloids (e.g., acridones) may be present.

If, in terms of the above criteria, the plant was considered of chemical interest, small samples of bark, wood, and leaves (and flowers or fruits if available) were collected. These samples, with the exception of wood, were preserved in envelopes (5 × 8 in.) pressed flat, in large sealed tins (2 gal. capacity) containing silica gel. In addition, confirmatory chemical tests (cf., Webb 1949, 1952*a*) were made at field headquarters of promising alkaloid plants. About 25 species were then (while in each area) collected in bulk (av. 10–20 lbs.) for detailed analysis in Australia. Air-drying and silica gel preservation were used for these samples. About 300 small samples (serving both for identification and chemical testing) were collected.

In Brisbane, samples were tested for alkaloids, using both hydrochloric acid and Prollius extracts, according to the methods outlined by Webb (1949, 1952*a*).

Plants were tested for saponins by the so-called froth test. The finely chopped material was boiled with water, cooled, and shaken. The production of a stable, characteristic "honeycomb" froth indicates the presence of saponin (cf., Dunstan, 1948).

The Liebermann-Burchard test was used to detect the presence of polycyclic substances. A small amount of dried, finely chopped material was treated, on a white spotting tile, with a few drops of acetic anhydride, then with 1–2 drops of concentrated sulphuric acid. Triterpenoids (in dicotyledons) give purple and pink colours, which are more persistent than the blue shades suggestive of steroids (chiefly in monocotyledons).

If both froth and Liebermann-Burchard tests, or froth test only, are positive, saponin is probably present. If only Liebermann-Burchard test is positive, then a free polycyclic substance may be present (Dunstan, 1948).

Samples were also tested for aluminium accumulation, using the method of Chenery (1948), and the results are published elsewhere (Webb, 1954).

In addition, other features of the plants such as presence of essential oils, foetid smell (e.g., methyl mercaptan), and pigments were noted. As specific tests were not applied, these data have been omitted.

Samples of reputed medicinal plants were collected for identification also, and this information will be published elsewhere.

For convenience, the families in Table 1 are arranged alphabetically. Brief comments, in terms of the Australian survey, are made concerning the phytochemical promise of each group. As specific identifications were not always possible, only the genus is given. Native names were noted for some of the plants and are given in Table 1 following the locality, in parentheses. The native names are in quotation marks followed by the name of the dialect. These are spelled phonetically, using the conventions of pidgin English (cf., Murphy, 1949). They are included with diffidence, but may serve, together with locality, to particularize the plants collected.

DISCUSSION

It is evident that numerous species of New Guinea flowering plants are worthy of detailed examination for alkaloids, saponins, pigments, cyanogenetic glycosides and other compounds. The present brief survey did not reveal any alkaloid-bearing families additional to those found in the Australian survey (Webb, 1953: 44). Additional genera containing alkaloids were found, however. Many positive genera have species endemic to New Guinea which should be systematically tested. The complexity of the flora requires search by, and co-operation with, experienced systematic botanists. Also, sampling of quadrats of adequate area (preferably several hectares), in which all species are differentiated, with the aid of competent natives if botanists are not available, would provide both useful phytochemical and ecological data. The relative inaccessibility of most areas of New Guinea requires special provision for on-the-spot drying of bulk samples for analysis, which should then be transported in air-tight containers. Record of authentic native name and dialect of the particular species facilitates further collections when a botanist is not in the area.

TABLE 2
SUMMARY OF SPOT-TEST RESULTS

	ALKALOID	FROTH	LB	FROTH & LB	TOTAL TESTED
Species . .	27	18	41	17	295
Genera . .	19	17	32	16	214
Families .	9	13	23	10	78

Alkaloids in 9 per cent, saponins in 12 per cent, free triterpenoids or steroids 14 per cent.

The Standing Committee of Pacific Botany, Pacific Science Association, formed a subcommittee on Medicinal Plants in 1953 (Chairman: Professor Ir. Kusnoto Setyodiwiryo). Also, the Pan Indian Ocean Scientific Congress held in Perth, West Australia, in 1954, discussed the organization of a joint drug plants survey. It is hoped that these practical efforts will result in a systematic, and long overdue, inventory of the plant products of the Indo-Malaysian region north of Australia.

TABLE 1

SUMMARY OF SPOT-TESTS OF PAPUA-NEW GUINEA PLANTS

(alk—alkaloid; froth—saponin; LB—Liebermann-Burchard test for polycyclic compounds; neg—all tests negative)

FAMILY AND GENUS	LOCALITY	RESULTS	COMMENTS
Acanthaceae			
Graptophyllum	Sogeri	1† neg	
Amaryllidaceae			
Crinum	Malahang	1 alk	Alkaloids likely in other spp.
Anacardiaceae			
Buchanania	Popondetta ("Siruga"—Orakaiva)	1 neg	No alkaloid promise; *Semecarpus* spp. have vesicant saps
Mangifera	Malahang	1 neg	
Annonaceae			
Cananga	Yalu	1 alk (trace)	Australian members not promising but more tropical New Guinea spp. worth systematic tests, including seeds
Goniothalamus	Lae	1 neg	
Polyalthia?	Popondetta ("Koro"—Orakaiva)	1 alk (trace)	
Apocynaceae			
Alstonia	Lae, Aiyura ("Iortna"—Gasup)	2 alk, LB	All spp. have alkaloids; triterpenes worth checking
Cerbera	Lae	1 neg	Seeds have cardiac glycoside
Ervatamia	Laloki R., Eilogo, Yalu	3 alk, 1 LB	Limited Australian experience suggests alks. relatively intractable
Ichnocarpus	Bisinumu	1 neg	
Rejoua	Lae	1 alk, LB	
Voacanga	Eilogo	1 alk	
Tribe Echitidae	Yalu	1 LB	The family is worthy of examination for triterpenoids; several other alkaloidal New Guinea spp. are available, e.g., *Melodinus* and *Ochrosia*
Aquifoliaceae			
Ilex	Wau, Nondugl ("Kamlins")	1 froth, LB	This family is not well represented locally
Araliaceae			
Boerlagiodendron?	Lae		
spp.	Malahang ("Sangara"), Aiyura ("Baki"—Gasup)	1 froth, LB	A family of great saponin interest, e.g., *Polyscias, Schefflera*
Aristolochiaceae			
Aristolochia	Malahang, Popondetta ("Holo"—Orakaiva)	2 alk (roots)	
Asclepiadaceae			
Dischidia	Bisinumu	1 LB	Cardiac glycosides in this family
Marsdenia	Aiyura ("Zunana"—Gasup)	2 neg	

TABLE 1—(Continued)

FAMILY AND GENUS	LOCALITY	RESULTS	COMMENTS
Barringtoniaceae			
Barringtonia	Sogeri	1 froth, LB	
Bignoniaceae			
Dolichandrone	Malahang	1 neg	
Boraginaceae			
Heliotropium	Laloki R.	1 neg	Some Australian spp. contain alkaloids and are toxic
Burseraceae			
Canarium	Lae, Aiyura ("Iampeika"—Gasup)	1 LB, 2 neg	
Chloranthaceae			
Ascarina	Nondugl ("Manggyi")	1 neg	
Combretaceae			
Terminalia	Popondetta ("Kauja"—Orakaiva)	1 froth (trace)	Yellow pigments of bark and leaves worth checking
Cucurbitaceae			
Sp.	Malahang ("Kunu")	1 froth	Bitter principles also occur in this sometimes toxic family
Cunoniaceae			
Opocunonia	Aiyura ("Narngkunda" & "Vinarka"—Gasup)	1 LB, 2 neg	A well-represented family of apparently little chemical interest on present standards
Pullea	Nondugl ("Wiyak")	1 neg	
Spp.	Nondugl ("Kuma," "Yak")	2 neg	
Datiscaceae			
Octomeles	Lae	1 LB	A small family in which unusual polycyclic bodies may be expected to occur
Dilleniaceae			
Dillenia	Lae	1 LB	
Tetracera	Malahang ("Tipepei")	1 neg	
Dioscoreaceae			
Dioscorea	Lae	1 LB	Steroid sapogenins probable
Dipterocarpaceae			
Anisoptera	Popondetta (? "Garawa"—Orakaiva)	1 neg	A characteristic group of little chemical interest on present standards
Hopea	Eilogo	1 neg	
Ebenaceae			
Diospyros	Wau, Nondugl ("Bunyum")	1 LB, 1 neg	Yellow pigment of bark and fruits worth checking
Elaeocarpaceae			
Elaeocarpus	Bisinumu, Aiyura ("Yohin"—Gasup)	3 neg	
*Sp.	Lae	1 froth	
Ericaceae			
Rhododendron	Wau, Nondugl ("Umbwam")	1 LB, 1 neg	

Escalloniaceae			
Carpodetus	Nondugl ("Kwong")	1 alk?	
Quintinia	Aiyura ("Amorpandu"—Gasup)	1 LB	
*Sp.		1 froth	
Euphorbiaceae			
Antidesma	Wau, Aiyura	2 neg	A large group, certainly of negligible alkaloid interest; triterpenes and proteolytic enzymes may be expected in some latex-bearing spp.
**Aporosa*	Aiyura	1 neg	
Baccaurea	Lae	1 neg	
Breynia	Malahang, Nondugl ("Bergu")	2 neg	
Bridelia	Popondetta ("Horogo"—Orakaiva)	1 neg	
Endospermum	Yalu	1 neg	
Glochidion	Lae, Wau, Nondugl ("Kiliman")	1 froth, 1 neg	
Macaranga	Malahang, Nondugl ("Kuma")	2 neg	
Mallotus	Malahang ("Kiauya")	1 neg	
Pimeleodendron	Lae	1 LB	
Spp.	Aiyura ("Kuwan"—Gasup), Keravat, Sogeri	6 neg	
Sect. Crotonoideae	Aiyura ("Bwakei"—Gasup), Popondetta ("Korina"—Orakaiva)	1 froth, 1 neg	
Fagaceae			
Castanopsis	Eilogo	1 froth, LB	
Lithocarpus	Aiyura ("Ortna"—Gasup)	1 froth	
Nothofagus	Nondugl ("Karap")	1 froth	
Pasania	Wau, Aiyura ("Yanuna"—Gasup), Nondugl ("Nongi")	1 froth, LB, 1 neg	
Polypodiaceae			
Cyclosorus	Malahang ("Balum")	1 neg	
Flacourtiaceae			
Pangium	Yalu, Sogeri, Popondetta ("Puga"—Orakaiva)	1 neg	
*Spp.	Nondugl ("Dolbot"), Popondetta ("Bareha"—Orakaiva)	2 neg	
Gesneriaceae			
Cyrtandra	Aiyura	1 LB	
Gnetaceae			
Gnetum	Bisinumu, Lae ("Ara")	1 alk (trace) froth (trace)	
Guttiferae			
Calophyllum	Aiyura ("Wandanamu"—Gasup)	1 neg	
Garcinia	Zenag, Nondugl ("Kitan"), Popondetta ("Susumi" and "Kaimusa"—Orakaiva)	1 froth, LB 2 neg	Yellow pigment
Himantandraceae			
Galbulimima	Aiyura ("Orfum"—Gasup)	1 alk	Two other spp. are recorded, and alkaloids would be expected
Icacinaceae			
**Platea*	Aiyura ("Ukuko"—Gasup)	1 LB	
**Tylecarpus?*	Popondetta ("Siganapa"—Orakaiva)	1 neg	
Sp.	Nondugl (? "Wi")	1 neg	

TABLE 1—(Continued)

FAMILY AND GENUS	LOCALITY	RESULTS	COMMENTS
Juglandaceae			
Engelhardtia	Eilogo	1 neg	
Lauraceae			
Actinodaphne	Lae	1 alk	
Cassytha	Malahang	1 alk	
Cinnamomum	Zenag, Wau, Popondetta ("Saruka"—Orakaiva)	2 neg	
Cryptocarya	Bisinumu, Aiyura ("Berpa"—Gasup)	5 neg	Alkaloids possible in some spp.; over 30 spp. of *Cryptocarya* are recorded
Endiandra	Aiyura	1 neg	
Litsea	Lae, Aiyura ("Bwa"—Gasup), Nondugl ("Nimbyilth"), Sogeri, Popondetta ("Okumba"—Orakaiva)	1 alk? 5 neg	But triterpenes worth checking
Pseudocryptocarya	Aiyura ("Antnu"—Gasup)	1 alk	Very closely related to the vesicant alkaloid-containing *Cryptocarya pleurosperma* of North Queensland
Leguminosae			
Albizia	Bisinumu	1 froth	
Archidendron	Lae, Aiyura ("Morkaia"—Gasup)	2 neg	
Crotalaria	Nondugl	1 neg	Alkaloid likely in some spp.
Inocarpus	Lae	1 neg	
Maniltoa	Lae	1 neg	
Piptadenia	Lae	1 alk?	
Pongamia	Lae	1 froth	
Pterocarpus	Lae ("Yomisa")	1 froth	
*Spp.	Keravat, Popondetta ("Haruma"—Orakaiva)	3 neg	
Liliaceae			
Cordyline	Malahang ("Si")	1 neg	
Dracaena	Eilogo	1 froth	Possible steroidal; sapogenins
Loganiaceae			
Couthovia	Laloki R., Sogeri, Popondetta (? "Paigarumba"—Orakaiva)	1 LB, 1 neg	
Geniostoma?	Wau	1 neg	
Fagraea	Sogeri	1 LB	
Strychnos	Wau	1 alk (trace)	
Lycopodiaceae			
Lycopodium	Nondugl	1 neg	
Magnoliaceae			
Elmerrillia	Eilogo	1 alk (trace)	Alkaloid worth following up, although Australian members negative
*Malvaceae(?)			
Sp.	Nondugl ("Kop")	1 alk (trace)	

Melastomataceae			
Alstronia	Wau, Edie, Ck., Popondetta ("Ahura"—Orakaiva)	3 neg	
Sp.	Nondugl ("Yimbi")	1 neg	
Meliaceae			
Aglaia	Wau, Sogeri, Popondetta ("Harei"—Orakaiva)	3 neg	
Cedrela	Nondugl ("Ongguna")	1 froth	
Chisocheton	Lae	2 neg	
Dysoxylum	Lae, Wau, Aiyura, Popondetta ("Sera"—Orakaiva)	2 alk? 1 froth, 1 LB, 1 neg	
**Walsura?*	Aiyura	1 neg	
Spp.	Aiyura (? "Ohya"—Gasup)	1 froth, 1 neg	
Menispermaceae			
Legnephora	Wau	1 alk	Alkaloid occurs mainly in root-bark
Stephania	Yalu	1 alk	Many other spp., all probably alkaloidal, are recorded
Spp.	Sogeri, Popondetta	2 alk	
Monimiaceae			
Hedycarya	Lae	1 neg	Several other New Guinea genera worth trying for alkaloid, e.g., *Anthobembix*, *Lauterbachia*
Kibara	Nondugl ("Kopul")	1 neg	
**Matthaea?*	Wau	1 neg	
Dryadodaphne	Aiyura ("Anonya"—Gasup), Nondugl ("Korin")	1 alk	
Sp.	Wau	1 neg	
Moraceae			
Antiaris	Keravat	1 neg	
Artocarpus	Lae, Aiyura ("Koorta"—Gasup), Popondetta	1 LB, 2 neg	
Ficus	Malahang ("Anda," "Mogi"), Aiyura ("Koiya"—Gasup)	2 neg	
Myristicaceae			
Horsfieldia	Lae	1 neg	
Myristica	Lae, Nondugl ("Gabnyas")	2 neg	
Sp.	Aiyura ("Narmpararu"—Gasup), Popondetta (? "Foren"—Orakaiva)	2 neg	
Myrsinaceae			
Maesa		1 neg	Pigments of fruits worth checking
Rapanea	Lae, Wau	2 LB	
Myrtaceae			
Octomyrtus	Nondugl ("Tambanei")	1 froth (trace)	
Syzygium	Lae, Aiyura ("Monu" & "Baiyuka"—Gasup), Nondugl ("Nantz"), Popondetta	1 froth, 2 LB, 2 neg	
Ochnaceae			
Brackenridgea	Eilogo	1 froth (trace)	
Olacaceae			
Ximenia	Popondetta ("Babuso"—Orakaiva)	1 neg	Leaves and fruits cyanogenetic

TABLE 1—(Continued)

FAMILY AND GENUS	LOCALITY	RESULTS	COMMENTS
Oleaceae			
Linociera	Aiyura	1 neg, 1 alk (trace)	
Spp.	Aiyura (? "Ohbiya"—Gasup)	1 neg	
Oxalidaceae			
Oxalis	Nondugl	1 neg	
Peripterygiaceae			
Peripterygium	Malahang	1 neg	
Piperaceae			
Piper	Lae, Yalu, Wau	3 neg	
Pittosporaceae			
Pittosporum	Edie Ck., Zenag, Aiyura (? "Aratna"—Gasup), Nondugl ("Milyun"), Sogeri	3 froth, 3 LB 2 neg	
Proteaceae			
Grevillea	Nondugl ("Kwimat")	1 neg	
Helicia	Nondugl ("Kimbront," "Arilt")	3 neg	
Rhamnaceae			
Emmenosperma	Popondetta ("Saraimbu"—Orakaiva)	1 froth	
Rosaceae			
Pygeum	Lae, Nondugl ("Bulnbat")	1 LB	Bark cyanogenetic
Rubiaceae			
Anthocephalus	Yalu, Popondetta	1 alk (trace)	So far, a disappointing family for alkaloids
Gardenia	Laloki R, Zenag, Nondugl ("Bulus")	1 froth, 3 LB	
Ixora	Lae	1 neg	
Mastixiodendron	Aiyura	1 alk?	
Morinda	Malahang ("Toon")	1 neg	
Mussaenda	Bisinumu, Yalu	2 neg	
Neonauclea	Lae	1 neg	
Opercularia?	Aiyura ("Malonka"—Gasup)	1 neg	Foetid, probably methyl mercaptan
Pavetta	Laloki R	1 alk (trace)	
Paederia	Rabaul	1 neg	Foetid, probably methyl mercaptan
Randia	Lae, Aiyura ("Opu"—Gasup), Popondetta ("Hara"—Orakaiva)	1 alk, 2 neg	Alkaloid may be unstable
Tarenna	Eilogo	1 LB	
Timonius	Zenag	1 LB	
Uncaria	Eilogo	1 alk (trace)	
Wendlandia	Wau	1 neg	
Spp.	Lae, Aiyura ("Sinakario"—Gasup), Nondugl ("Misik" & "Topnam"), Popondetta	1 alk? 1 froth 1 LB, 4 neg	

Rutaceae			
Acronychia	Aiyura, Garoka, Aiyura ("Durp")	4 neg	Numerous other New Guinea spp. worth trying for alkaloids; about 18 *Acronychia*, 57 *Evodia*, and 23 *Melicope* spp. are recorded
Evodia	Bisinumu, Eilogo, Lae, Zenag, Wau, Edie Crk., Aiyura ("Ohday"—Gasup), Popondetta	2 alk, 7 neg	
Flindersia	Wau	1 neg	
Glycosmis	Laloki R	1 alk	
Halfordia	Aiyura	1 alk	
Melicope	Wau, Nondugl ("Liling")	2 neg	
Zanthoxylum	Aiyura ("Amuka"—Gasup)	1 neg	
Sapindaceae			
Allophylus	Lae	2 neg	A family of obvious saponin interest
Arytera	Sogeri	1 froth	
Ganophyllum	Lae	1 froth	
Pometia	Yalu, Popondetta ("Hoijanu"—Orakaiva)	1 froth, LB	
Tristiropsis	Lae	1 froth, LB	
Spp.	Lae, Aiyura, Nondugl ("Yimyih"), Popondetta ("Umbupu"—Orakaiva)	2 froth, LB, 3 neg	
Sapotaceae			
**Chrysophyllum*	Popondetta ("Djirihu"—Orakaiva)	1 neg	Latex of these spp. may be attractive to triterpene chemists
Palaquium	Lae	1 neg	
Planchonella	Lae, Aiyura ("Iapa"—Gasup), Popondetta ("Tiga" and "Jipapa"—Orakaiva)	2 LB, 2 neg	
Saurauiaceae			
Saurauia	Lae, Aiyura ("Kasu"—Gasup)	1 neg	
Simaroubaceae			
Ailanthus?	Popondetta ("Jandopupa"—Orakaiva)	1 neg	
Picrasma	Popondetta ("Haisipa"—Orakaiva)	1 alk?	Bark very bitter
Sterculiaceae			
Commersonia	Lae	1 neg	
Pterocymbium	Yalu	1 neg	
Symplocaceae			
Symplocos?	Nondugl ("Minyam")	1 froth, LB	
Theaceae			
Gordonia	Nondugl ("Kauragu" and "Kapakup")	1 froth, LB	
Ternstroemia	Popondetta ("Sisingi"—Orakaiva)	1 froth, LB	
*Sp.	Nondugl (? "Gaindu")	1 neg	
Thymelaeaceae			
Phaleria	Lae	1 neg	
Trimeniaceae			
Trimenia	Edie Ck.	1 neg	Bark very bitter
Urticaceae			
Laportea	Yalu	1 neg	Has irritant stinging hairs
Leucosyke	Lae	1 neg	
Sp.	Malahang ("Kavisa," "Salat")	1 neg	

TABLE 1—(Continued)

FAMILY AND GENUS	LOCALITY	RESULTS	COMMENTS
Vacciniaceae			
Agapetes	Wau	1 LB	
Vaccinium	Wau	1 LB, froth (trace)	
*Spp.	Nondugl ("Kapikap")	1 LB	
Verbenaceae			
Callicarpa	Lae, Zenag	1 neg, 1 LB	
Gmelina	Aiyura ("Kauia"—Gasup)	1 froth	
Vitex	Popondetta ("Sisaru"—Orakaiva)	1 LB	
Family Unplaced			
Spp.		2 LB, 2 neg	
Families not tested, but of interest:			
Erythroxylaceae	Alkaloids probably present in bark and leaves of *Erythroxylon* spp.		
Hernandiaceae	*Hernandia papuana* bark probably alkaloidal		

*Determinations based on wood only.
† Numerals refer to the number of species tested.

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The Inshore Fish Fauna of Johnston Island, a Central Pacific Atoll[1]

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INTRODUCTION

THIS PAPER is primarily concerned with Central Pacific zoogeography. Its main purpose is to trace in so far as possible the derivation and the immigration and emigration routes of the Johnston Island inshore fish fauna. The importance of Johnston for a study of this sort lies in its position between the areas inhabited by the great tropical Pacific fauna to the south and the strongly endemic Hawaiian fauna to the north (Fig. 1).

The first section of this paper records the fishes known from Johnston and presents the taxonomic interpretations upon which the zoogeographic treatment of the second section is based.

Of the collections dealt with, the most important for this paper are those taken by V. E. Brock, Y. Yamaguchi, and the author at Johnston in February 1951. These collections were made possible through the kindness of Colonel Cronau, then commanding officer of the island, and were greatly facilitated by Lt. Col. Eaton and other members of the airforce who were there at the time. In addition, three small collections from the same island were turned over to me by Brock, Schaefer, and Francis respectively. Finally, a reexamination of certain fishes from Johnston recorded by Fowler and Ball (1925) was made possible through the courtesy of the staff of the Bernice P. Bishop Museum.

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SECTION 1. FISHES RECORDED FROM JOHNSTON ISLAND

Except for Schultz's (1950: 548) reference to *Cirrhitus alternatus*, the following four works include or cite all of the published records on Johnston fishes.

Smith and Swain (1882) recorded 27 species from the island, 5 of which they described as new.

Fowler and Ball (1925) listed 72 species from Johnston collected by the "Tanager" Expedition of 1923. One of these was described as new.

Schultz and collaborators (1953) in the first volume of their report on "Fishes of the Marshall and Marianas Islands" recorded specimens of about 9 Johnston species. Most of these were referred to only in passing, e.g., in tables; three, however, were described as new.

Halstead and Bunker (1954), in a report on fish poisoning at Johnston Island, listed 60 species investigated.

One hundred and eighteen species of Johnston fishes have been seen by the present author. Species recorded from the island that have not been seen are marked in the species accounts with an asterisk; some of these almost certainly represent misidentifications and others equally certainly do not, but any attempt to decide which are which would only lead to further misidentifications.

It is easy to criticize others for recording species without also providing sufficient descriptive material to determine whether the record has been correctly identified. It is more

difficult to write a paper that does not commit the same error and is still sufficiently brief to be publishable. The present account attempts a compromise between these two pitfalls. Species which are sufficiently distinct to be readily recognizable, about which there are at present no zoological or nomenclatorial questions, and whose presence at Johnston there is no zoogeographic reason to doubt, have been recorded by name only. For the others an attempt has been made to give the diagnostic characters of the Johnston specimens on the basis of which the species identification was made. It is clearly recognized that this method only alleviates, and by no means eliminates, the faults of recording species by name only.

This section contains notes on the classification of certain species of *Uropterygius*, *Belone*, *Pseudamiops*, *Scarus*, and *Scorpaena* as well as the records of Johnston fishes. Families are listed in "phylogenetic sequence"; genera and species within the family are taken up alphabetically. Identifications and nomenclature follow Schultz, *et al.* (*op. cit.*) where possible, and various authors for the remaining species. All lengths given in millimeters are standard lengths; total lengths are expressed in inches.

MYLIOBATIDAE

***Aetobatus narinari** (Euphrasen)

Fowler and Ball, 1925, 1 spec.; Halstead and Bunker, 1954, 1 spec.

SYNODONTIDAE

Saurida gracilis (Quoy and Gaimard)

5 specs., 69–110 mm., 1951; 1 spec., Brock, 1948.

A double band of teeth on each side of the palate; inner rays of pelvic fins contained about 1.2 times in the length of the outermost rays.

Synodus binotatus Schultz

3 specs., 46–77 mm., 1951.

A single row of teeth on each side of palate; three and a half scale rows between the lateral line and the dorsal origin; peritoneum pale; no black spot on opercle but a dark mark on tip of snout and three dark rings on the back behind the dorsal fin; 9 anal rays; tips of first dorsal rays not reaching tips of succeeding rays when the fin is depressed; dorsal origin equidistant from tip of snout and origin of adipose; tips of central caudal rays not black (cf., Schultz, *et al.*, 1953: 30, 31).

CONGRIDAE

Conger noordziekii Bleeker

1 spec., 255 mm., 1951.

Origin of dorsal over anterior third of the depressed pectorals; a dark longitudinal line extending below and behind eye.

OPHICHTHIDAE

Brachysomophis sauropsis Schultz

1 spec., 362 mm., 1951.

As compared with a 1070 mm. specimen of *Brachysomophis henshawi* from Hawaii, the Johnston specimen differs in having the distance from the tip of snout to the posterior border of the eye contained 9 times in the head length to gill openings instead of 7.2 times, in having the dorsal and anal fins low (the anal does not even extend above the groove that encloses it) and light in coloration instead of well-developed and with the dorsal black-based; in having the pores of the head and body not enclosed in dark areas; and in having no dark bands either along the mid-dorsal line or along the lateral line area of the sides. The Johnston specimen agrees in every way with Schultz's original description of *Brachysomophis sauropsis*.

Leiuranus semicinctus (Lay and Bennett)

6 specs., 133–227 mm., 1951. Fowler and Ball, 1925, 3 specs.

Ovate black saddles about equal in maximum width to the interspaces between them.

Leptenchelys labialis (Seale)

2 specs., 121–134 mm., 1951.

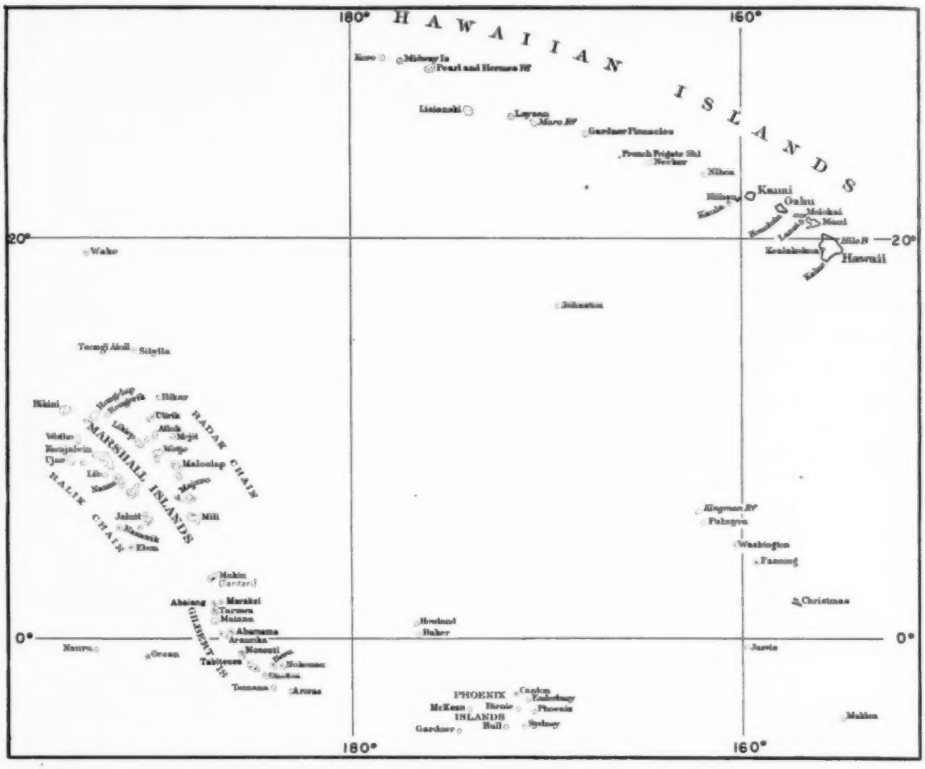

FIG. 1. Chart of the region surrounding Johnston Island. From U. S. Hydrographic Chart 1500, 47th edition.

Ventral surface of snout with a median groove that contains teeth; caudal fin well developed; dorsal origin a little over a head length behind head (cf., Schultz, *et al.*, 1953: 71).

I have dealt elsewhere (1950: 312–314; 1952: 300–306) at some length with the reasons why *Leptenchelys*, *Muraenichthys*, and *Schultzidia* should be placed in the Ophichthidae.

Muraenichthys cookei Fowler

12 specs., 103–173 mm., 1951.

Posterior rim of orbit about over rictus; dorsal origin from 2 to 5 eye diameters ahead of anus; vomerine teeth uniserial (cf., Schultz, *et al.*, 1953: 71, 72).

These specimens are discussed in section 2.

Muraenichthys gymnotus Bleeker

3 specs., 52–118 mm., 1951.

Dorsal fin originating about half a head length behind the anus; rear margin of eye slightly ahead of rictus; teeth on front of maxillary and dentary at least double-rowed; snout sharp, the distance from its tip to the rictus contained about 3.7 times in the head length (cf., Schultz, *et al.*, 1953: 71–73).

Muraenichthys schultzei Bleeker

3 specs., 106–117 mm., 1951. Fowler and Ball, 1925, 12 specs.

Dorsal origin about two-thirds of a head length behind anus; snout bluntly rounded; vomerine teeth two-rowed (cf., Schultz, *et al.*, 1953: 71–73).

Myrichthys bleekeri Gosline

1 spec., 365 mm., 1951. As *Myrichthys colubrinus*, Fowler and Ball, 1925, 12 specs.

Width of black band over gill opening contained two times in the white interspace behind it; only the last two bands completely encircling the body.

Myrichthys maculosus (Cuvier)

5 specs., 275–865 mm., 1951. Fowler and Ball, 1925, 1 spec. As *Myrichthys stypurus* Smith and Swain, 1882, 1 spec.

Round black spots on a greenish background.

Schultzidia johnstonensis (Schultz and Woods)

2 specs., 101–167 mm., 1951. Schultz, *et al.*, 1953, 1 spec.

Maxillary teeth small, in several rows, facing inward; vomerine teeth minute in the small specimen, apparently absent in the larger; no median papilla on upper lip between nostrils (cf., Schultz, *et al.*, 1953: 71).

MORINGUIDAE

Moringua macrochir Bleeker

5 specs., 128–262 mm., 1951.

Lower jaw projecting; lateral line pores 98–110.

The name used for this species follows Gosline and Strasburg (In press).

MURAENIDAE

Anarchias allardicei Jordan and Starks

5 specs., 121–135 mm., 1951.

Pore near posterior nostril lying somewhat ahead of nostril; body color plain brown, the brownish color provided by microscopic brown speckling on a light background (cf., Schultz, *et al.*, 1953: 139).

Anarchias cantonensis (Schultz)

3 specs., 142–163 mm., 1951.

Pore near posterior nostril lying somewhat ahead of nostril; body with a reticulate pattern of dark on light; chin barred (cf., Schultz, *et al.*, 1953: 139).

Anarchias leucurus (Snyder)

35 specs., 103–176 mm., 1951.

Pore near posterior nostril lying slightly behind nostril; body with a reticulate pattern; chin barred (cf., Schultz, *et al.*, 1953: 139).

Echidna leucotaenia Schultz

5 specs., 150–240 mm., 1951.

Body plain brown; fins black-based and white-edged; lower jaw light except for a brown patch below each eye (cf., Schultz, *et al.*, 1953: 100).

Echidna polyzona (Richardson)

1 spec., 63 mm., 1951.

Pebble-like teeth on vomer; about 27 dark bands on body (cf., Schultz, *et al.*, 1953: 100).

Echidna zebra (Shaw)

1 spec., 850 mm., 1951.

Anus well behind middle of body length; black and white stripes on body (cf., Schultz, *et al.*, 1953: 100).

***Gymnothorax buroensis** Bleeker

Halstead and Bunker, 1954, 5 specs. It seems most likely that Halstead and Bunker's record refers to *Gymnothorax eurostus*, the Hawaiian form of *G. buroensis*. Indeed, since none of the Hawaiian "endemic" species are recorded by Halstead and Bunker, such of this element in the Johnston fauna as was taken by these authors must have been misidentified.

Gymnothorax eurostus (Abbott)

20 specs., 158–500 mm., 1951.

Premaxillary teeth divisible into 5 series, these somewhat difficult to distinguish in large specimens; no black blotch surrounding gill opening; body mottled (cf., Schultz, *et al.*, 1953: 109).

These specimens are dealt with in section 2.

Gymnothorax gracilicaudus Jenkins

3 specs., 106–140 mm., 1951.

Teeth not serrate, in three series on premaxillary, those of the median row notably enlarged. Body light with irregular dark ver-

tical bands; no black blotch around gill opening; a prominent white band down the midline of the snout; median fins with broad, plain, light borders; dark pigment forming an irregular band extending from behind eye across rictus; chin and abdomen light; a dark saddle running across top of head and down at least to the level of the eye on either side.

***Gymnothorax javanicus** (Bleeker)

Halstead and Bunker, 1954, 2 specs.

Gymnothorax meleagris (Shaw)

3 specs., 230–670 mm., 1951. Fowler and Ball, 1925, 2 specs.; Halstead and Bunker, 1954, 2 specs.

Five rows of teeth on premaxillary; gill opening in a black area; small, round, white spots on a dark ground.

Gymnothorax moluccensis (Bleeker)

1 spec., 257 mm., 1951.

Larger, lateral teeth in both jaws serrate. Body plain brown (cf., Schultz, *et al.*, 1953: 109).

Gymnothorax pictus (Ahl)

As *Lycodontis picta*, Fowler and Ball, 1925, 2 specs., one of these reexamined.

Gymnothorax undulatus (Lacépède)

2 specs., 250 and 850 mm., 1951.

Premaxillary teeth in three series, the central teeth fang-like. Body dark, with narrow white reticulations forming irregular vertical lines; no white streak on snout (cf., Schultz, *et al.*, 1953: 109–113).

Rabula fuscomaculata Schultz

19 specs., 116–149 mm., 1951. Schultz, *et al.*, 1953, 16 specs.

Dorsal fin commencing somewhat less than a head length ahead of anus; dark spots and reticulations on a light ground (cf., Schultz, *et al.*, 1953: 139).

Uropterygius dentatus Schultz

1 spec., 366 mm., 1951. Schultz, *et al.*, 1953, 373 mm., holotype.

Mottled with dark spots, those posteriorly more or less united into irregular vertical bars; vomerine teeth either absent or made up of a short posterior continuation of the median premaxillary row; both anterior and posterior nostrils pigmented though less so than the rest of the head; gill opening high on the sides.

This specimen seems to be more or less intermediate between *U. dentatus* and *U. supraforatus*. Indeed the distinctions between these two species as given by Schultz (in Schultz, *et al.*, 1953: 141) do not seem to be very clear-cut. Nevertheless, it seems best to follow Schultz in recognizing the Johnston form as *U. dentatus*, at least until such time as specimens of *U. supraforatus* become available for comparison.

For the relationships between *U. dentatus* and *U. fuscoguttatus*, see the account of the latter species.

Uropterygius fuscoguttatus Schultz

3 specs., 129–152 mm., 1951. Schultz, *et al.*, 1953, 1 spec.

At the present time there seem to be three recognized Central Pacific species in the *Uropterygius* group with the gill openings high on the sides and multiserial teeth in both jaws: *U. supraforatus* Regan, *U. dentatus* Schultz, and *U. fuscoguttatus* Schultz. Unfortunately, Schultz has placed his two species, both of which according to specimens and his own figures (in Schultz, *et al.*, 1953: figs. 32, 33) have the gill opening about equally high on the sides, on opposite sides of a major break in his key based on the level of the gill openings. Actually *U. fuscoguttatus* is rather difficult to distinguish from *U. supraforatus* and *U. dentatus*. As compared with these, *U. fuscoguttatus*, judging from Hawaii and Johnston material, is a relatively small species, not attaining a length of over 285 mm. A female 185 mm. is ripe. From *U. dentatus* it can best be distinguished by coloration: *U. dentatus* is an eel with dark spotting and mottling everywhere; *U. fuscoguttatus*, by contrast, is spotted and mottled posteriorly, but the head and fore-

part of body are plain brown, the brownish color made up of minute, regularly spaced punctulations. In addition *U. fuscoguttatus* has a somewhat longer snout; the distance between the posterior margin of the eye and the most posterior maxillary tooth is considerably less than the distance from the tip of the snout to the posterior nostril (in *U. dentatus* these two distances are about equal). In *U. dentatus* the two jaws are about equal, and the distance from the tip of chin to the most posterior mandibular tooth is contained about 2.4 times in the head length; in *U. fuscoguttatus* the lower jaw is very slightly inferior, and the distance from the tip of the chin to the last mandibular tooth is contained about 2.7 times in the head length. There are also many more teeth in *U. dentatus* than in *U. fuscoguttatus* but since the teeth are multiserial in both species, this difference is difficult to quantify. The features listed above would be adequate for distinguishing the two species if they were the same size. Unfortunately they are not. The largest known specimen of *U. fuscoguttatus* is one from Hawaii measuring 285 mm.; the smallest of the three known specimens of *U. dentatus* is 363 mm.

Uropterygius polyspilus Regan

2 specs., 150 and 180 mm., 1951.

Anus very slightly behind middle of the total length; prominent, roundish dark spots on a light brown background; tip of snout white in alcohol, yellow in life.

Uropterygius tigrinus (Lesson)

2 specs., 670 and 680 mm., 1951. As *Gymnomuraena tigrina*, Smith and Swain, 1882, 1 spec.

Anus far behind middle of total length; prominent, roundish dark spots on a light brown background; snout of the same color as the rest of the body but speckled rather than spotted.

BELONIDAE

Belone platyura Bennett

1 spec., 295 mm., 1951. Halstead and Bunker, 1954, 1 spec. As *Belone persimilis*, Schultz, *et al.*, 1953, 4 specs.

The relationship between *Belone platyura* and *B. persimilis* needs clarification. *B. persimilis* was first differentiated from *B. platyura* by Günther (1909: 340, text fig.) on the basis of the smaller eye. In order to demonstrate this, Günther compared the eye size with the interorbital and with the postorbital head length in the two species (Table 1). In 1943 Schultz (p. 54) placed *B. persimilis* in the synonymy of *B. platyura*, stating: "After measuring a large series of specimens of the large-eyed form *B. platyura* and many of the small-eyed form named by Günther *B. persimilis*, I am of the opinion that when small this species has a small eye and when larger the eye is much larger in proportion." In 1953 Schultz (p. 160) reseparated the two nominal species on the basis of eye size and the relatively shorter postorbital head length of *B. persimilis*. He compared these two characters with one another and each of them with the distance between the pelvic insertion and the anal origin in the two species (Table 1). Whereas Günther believed the two species occurred together over a wide area, Schultz (1953, *loc. cit.*) considered all of his Marshallese material to represent *B. platyura* and all of the Johnston (and by inference Hawaiian) specimens to be *B. persimilis*.

Counts and measurements of the six specimens available to me are given in Table 1. Aside from the characters listed, an attempt was made to find others which might be used for differentiating two species. For example, the length of the anal base was compared with the postanal length, but it was found that this comparison merely demonstrated the difference in the number of anal rays. Again, the Johnston and the larger Hawaiian specimen at present lack cheek scales whereas the other four have such scales, but this may be an artifact of preservation. At first it was thought possible to separate a long, narrow-headed species from one with a relatively short and broad head (the smaller Hawaiian and the

TABLE 1

CERTAIN COUNTS, MEASUREMENTS, AND DIFFERENCES BETWEEN *Belone persimilis?* AND *Belone platyura*
Measurements, except the first, are given in thousandths of the body length as defined

	Belone persimilis?			*Belone platyura*		
	Oahu	Oahu	Johnston	Gilberts	Gilberts	Bikini
Body length, from front of eye to tip of fleshy projection on middle caudal rays.	255 mm.	272 mm.	299 mm.	230 mm.	278 mm.	297 mm.
Distance from front of nasal bones to anterior nostril	35.3	34.5	36.8	33.3	38.1	36.4
Horizontal orbit diameter	45.2	45.0	44.2	46.1	47.8	50.2
Postorbital head length	76.2	76.8	73.4	81.3	82.8	77.7
Width of skull in front of eye	51.1	50.9	51.2	46.5	56.8	57.2
Width of bony interorbital	36.5	37.0	34.5	39.1	43.8	43.1
Maximum width of skull across pterotics	52.5	53.7	53.2	45.9	62.2	62.3
Distance from pelvic insertion to anal origin	184	182	181	189	192	174
Dorsal rays	14	14	14	13	14	14
Anal rays	18	19	19	17	18	18
Pectoral rays	12	12	12	12	12	12
Orbit into bony interorbital:						
Present data	0.81 to 1.1			0.85 to 0.92		
According to Günther (1909)	less than (soft?) interorbital			equals (soft?) interorbital		
Orbit into postorbital head:						
Present data	1.67 to 1.70			1.55 to 1.75		
According to Günther (1909)	1.6 to 2			1.5 to 1.67		
According to Schultz (1953)	1.8 to 2.1			1.5 to 1.8		
Orbit into pelvic-anal distance						
Present data	4.1 to 4.2			3.5 to 4.1		
According to Schultz (1953)	4.0 to 5.1			3.1 to 3.6		
Postorbital head length into pelvic-anal distance:						
Present data	2.3 to 2.5			2.2 to 2.3		
According to Schultz (1953)	2.3 to 2.5			2.0 to 2.2		

smaller Gilbertese specimen would constitute the narrow-headed form) but this idea was discarded. In the final analysis it appears that if any separation of two species among the tabulated specimens is made, it should be based on the size of the eye. However, the difference in eye size between the specimens in Table 1 labelled *B. persimilis?* and those labelled *B. platyura* is very slight, and from the Table it is obvious that to state this difference in relation to the interorbital width, the postorbital head length, and only to a lesser extent the pelvic-anal distance obscures rather than clarifies the segregation of two forms. In short, of the characters used by Günther and by Schultz (1953), only two of them will serve to separate the specimens at hand, and even in these there may prove to be more of a continuous distribution than a separation. Under the circumstances it seems that a convincing means of differentiating *B. persimilis* from *B. platyura*, if both species are valid, remains to be demonstrated; meanwhile there is little practical use in recognizing them. Finally, if the two prove valid, then the nomenclatorial question will arise as to whether the second should be called *B. persimilis*, *B. carinata* (described from the Hawaiian Islands by Cuvier and Valenciennes in 1846), or perhaps by some other early name.

HEMIRAMPHIDAE

Hyporhamphus acutus (Günther)
2 specs., 80 and 163 mm., 1951.

Upper jaw scaled; greatest diameter of the nasal fossa about one third the diameter of the orbit; posterolateral border of fossa with a prominent bony rim; sensory pore on preorbital apparently branched above with a pore in front of eye and another near nasal fossa; inner pelvic ray not elongate. Dorsal base very slightly shorter than base of anal; dorsal with 14 rays, anal with 18 in larger specimen.

The identification of these specimens seems certain, except that the small diameter of the nasal fossa throws them into the genus *Hemiramphus* according to Schultz and Woods' generic key (in Schultz, *et al.*, 1953: 166). Measurement of other available specimens of the same species including Bikini duplicates indicates that the key character referred to will not serve for this species.

EXOCOETIDAE

***Cypselurus poecilopterus** (Valenciennes)
Fowler and Ball, 1925, 2 specs.

***Cypselurus simus** (Valenciennes)
Fowler and Ball, 1925, 1 spec.

AULOSTOMIDAE

***Aulostomus chinensis** (Linnaeus)
Smith and Swain, 1882, 1 spec.; Halstead and Bunker, 1954, 5 specs.

FISTULARIIDAE

Fistularia petimba Lacepède
1 spec., 900 mm., 1951. Fowler and Ball, 1925, 1 spec.

HOLOCENTRIDAE

Holocentrus lacteoguttatus Cuvier
10 specs., 54–109 mm., 1951; 2 specs., 97 and 101 mm., Brock, 1948. Fowler and Ball, 1925, 5 specs.; Halstead and Bunker, 1954, 2 specs.

The two opercular spines subequal in size; body speckled with sooty marks.

Holocentrus microstomus Günther
Fowler and Ball, 1925, 2 specs., one of these reexamined.

Dorsal XI–12; perforated scales in lateral line 48; longest anal spine reaching beyond caudal base.

Holocentrus sammara (Forskål)
3 specs., 117–157 mm., 1951. Halstead and Bunker, 1954, 1 spec.

Brown spotting on a bronze to silvery background; a large dark blotch on the spinous dorsal.

Holocentrus spinifer (Forskål)
4 specs., 151–300 mm., 1951; 1 spec., 261 mm., Schaefer, 1948. Fowler and Ball, 1925, 6 specs.; Halstead and Bunker, 1954, 7 specs. As *Holocentrus leo*, Smith and Swain, 1882, 2 specs.

Holocentrus tiere Cuvier and Valenciennes
8 specs., 121–226 mm., 1951. Halstead and Bunker, 1954, 3 specs. As *Holocentrus erythraeus*, Smith and Swain, 1882, 2 specs.

Perforated scales in the lateral line 50; maxillary longer than eye; dorsal XI–14.

Holotrachys lima (Valenciennes)
1 spec., 115 mm., 1951.

Myripristis argyromus Jordan and Evermann
31 specs., 45–210 mm., 1951; 1 spec., 121 mm., Brock, 1948. Halstead and Bunker, 1954, 3 specs. As *Myripristis murdjan*, Fowler and Ball, 1925, 1 spec., this specimen reexamined.

Perforated scales in the lateral line 34; anal IV, 13; gill rakers 12 + 1 + 25 = 38; interorbital width contained about 3.7 times in the head length.

***Myripristis berndti** Jordan and Evermann
Halstead and Bunker, 1954, 1 spec.

APOGONIDAE

Apogon erythrinus Snyder
15 specs., 30–42 mm., 1951.

Dorsal VI–I, 9; anterior margin of preopercle smooth; anal II, 8; lateral line complete; second spine of first dorsal much longer than third (cf., Lachner, *in* Schultz, *et al.*, 1953: 435).

Apogon menesemus Jenkins

13 specs., 67–128 mm., 1951; 1 spec., 86 mm., Brock, 1948.

Dorsal VII–I, 9; both margins of preopercle serrate; palatine teeth absent; gill rakers (including rudiments) 4 + 1 + 17 = 22; black pigmentation on caudal forming a complete arc.

Apogon snyderi Jordan and Evermann

31 specs., 32–100 mm., 1951; 2 specs., 40 and 97 mm., Brock, 1948. As *Apogon frenatus*, at least in part, Fowler and Ball, 1925, 6 specs.

Dorsal VII–I, 9; both margins of preopercle serrate; palatine teeth present; gill rakers (including rudiments) 4 + 1 + 13 = 18; no circular spot at midbase of caudal fin in specimens over 55 mm. but instead a dark bar that covers the whole fin base; in specimens 50–55 mm. a more or less well-delimited, round dark spot that lies above but touches the lateral line; stripe on sides not well-marked, absent in large specimens; serrations on anterior margin of preopercle reaching a larger size than those on posterior margin; suborbital serrations few in small specimens, numerous in large, but almost always more than 3 (cf., Lachner, in Schultz, *et al.*, 1953: 436, 437).

Apogon waikiki (Jordan and Evermann)

3 specs., 21–36 mm., 1951.

Dorsal VII–I, 9; no serrations on preopercle; palate toothless; lateral line complete; dorsal fin without ocellus; dorsal rounded, dusky at base, the tips of the outer rays white.

Pseudamiops gracilicauda (Lachner)

1 spec., 23 mm., 1951.

Recently Smith (1954) has described the new genus *Pseudamiops* for the single new species *P. pellucidus*. In the same article (p. 794) he erects the "provisional" genus *Lachneria* for the species *Gymnapogon gracilicauda* Lachner. The difference between the two genera according to the descriptions is that *Pseudamiops* is scaled and the specimens on which *Gymnapogon gracilicauda* was based were naked. Smith suspected that the scales of *G. gracilicauda* had been rubbed off; hence the provisional nature of his genus *Lachneria*. The specimen from Johnston plus two Hawaiian specimens agree well with Lachner's description of *Gymnapogon gracilicauda* except that they are more or less scaled. However, as with *Pseudamiops pellucidus*, the scales are apparently highly deciduous, for none of the three specimens are now completely scaled.

The chief points, aside from squamation, in which the Johnston and Hawaii specimens differ from Lachner's description and figure (in Schultz, *et al.*, 1953: 497, 498, fig. 84) are the following. The present specimens have a very pinched-in abdominal region as though the fishes had been starving; the specimen figured by Lachner does not have this feature, nor does that of *Pseudamiops* figured by Smith. The longest spine of the anal and that of the second dorsal are about half the length of the succeeding soft ray, instead of about four fifths the length of these rays as shown in Lachner's figure. The middle pectoral rays terminate in elongate, soft, fragile filaments. There seem to be at most 6 or 7 teeth on the vomer instead of about 20 according to Lachner (the vomerine teeth of *Pseudamiops* are reduced to one or two). There are no weak spines on the operculum; two are said to be present in *Gymnapogon gracilicauda*. Finally, only one of the three specimens has the system of papillae on the head well developed; however, as Smith has noted the prominence of this character probably varies with the nature of preservation.

From *Pseudamiops pellucidus* the Hawaiian and Johnston specimens differ in having one fewer soft anal ray and in lacking the pigment spots on the head.

It may prove to be that the Hawaiian and Johnston material is a separate species from both Lachner's Marshallese form and Smith's from Africa. However, as Lachner's material was in poor condition it will apparently require comparison with better Marshallese

material to determine whether the Hawaiian form is conspecific with it or not.

No such doubt seems possible regarding the necessity of placing the genus *Lachneria* in the synonymy of *Pseudamiops*.

KUHLIIDAE

Kuhlia marginata (Cuvier and Valenciennes)

9 specs., 61–221 mm., 1951. As *Kuhlia taeniura*, Smith and Swain, 1882, 2 specs.

These specimens will be dealt with in section 2.

PSEUDOCHROMIDAE

Pseudogramma polyacantha (Bleeker)

11 specs., 39–74 mm., 1951; 4 specs., 35–51 mm., Brock, 1948.

Dorsal spines VII; no enlarged pores between the eyes.

PRIACANTHIDAE

Priacanthus cruentatus (Lacepède)

2 specs., 127 and 140 mm., 1951; 4 specs., 89–93 mm., Francis, 1948. Halstead and Bunker, 1954, 2 specs.

Soft dorsal rays 13; soft anal rays 14; no dark spots on pelvic fins; caudal fin truncate.

SERRANIDAE

***Pristipomoides sieboldii**

Fowler and Ball, 1925, 1 spec.

KYPHOSIDAE

***Kyphosus bigibbus** Lacepède

Halstead and Bunker, 1954, 1 spec.

Kyphosus vaigiensis (Quoy and Gaimard)

1 spec., 170 mm., 1951.

Longest dorsal spine longer than longest soft dorsal ray; dorsal XI, 13; anal III, 12 or 13; greatest depth 2.3 in standard length.

MULLIDAE

***Mulloidichthys auriflamma** (Forskål)

Halstead and Bunker, 1954, 2 specs. As *Upeneus vanicolensis*, Smith and Swain, 1882, 1 spec. As *Mulloides auriflamma* Fowler and Ball, 1925, 4 specs.

Mulloidichthys samoensis (Günther)

5 specs., 162–219 mm., 1951; 6 specs., 92–101 mm., Francis, 1948; 9 specs., 124–143 mm., Schaefer, 1948. Halstead and Bunker, 1954, 7 specs. As *Upeneus preorbitalis* Smith and Swain, 1882, 1 spec.

A black spot on sides below spinous dorsal; a dark area on inside of gill cover ahead of pseudobranch.

Parupeneus barberinus (Lacepède)

As *Upeneus barberinus*, Fowler and Ball, 1925, 1 spec., this reexamined.

Parupeneus bifasciatus (Lacepède)

8 specs., 53–210 mm., 1951. Halstead and Bunker, 1954, 3 specs. As *Parupeneus crassilabris*, Smith and Swain, 1882.

Depth of body greater than the head length; barbels short, failing to reach the pelvic bases by about three and a half scales; body usually with vertical dark bands, one of these with its anterior border about even with a line drawn between the soft dorsal and anal origins.

***Parupeneus chryserydros** (Lacepède)

Halstead and Bunker, 1954, 2 specs. As *Upeneus chryserydros*, Fowler and Ball, 1925, 1 spec.

***Parupeneus crassilabris** (Valenciennes)

Halstead and Bunker, 1954, 1 spec.

Parupeneus multifasciatus (Quoy and Gaimard)

3 specs., 175–220 mm., 1951. As *Upeneus velifer* Smith and Swain, 1882, 1 spec.

Depth of body less than the head length; barbels long, failing to reach the pelvic origins by 1 scale; body with dark vertical blotches, one of these with its anterior border extending downward and forward from the last ray of the first dorsal.

***Parupeneus trifasciatus** (Lacepède)

Halstead and Bunker, 1954, 4 specs.

CIRRHITIDAE

Cirrhitus alternatus Gill

1 spec., 72 mm., 1951; 1 spec., 119 mm., Brock, 1948. As *Cirrhitus maculatus*, Fowler and Ball, 1925, 1 spec.

These specimens are dealt with in section 2.

Paracirrhites bimacula (Jenkins)

13 specs., 28–60 mm., 1951.

CARANGIDAE

Carangoides ferdau jordani Nichols

1 spec., 318 mm., 1951. Halstead and Bunker, 1954, 5 specs.

Teeth in bands in both jaws; breast naked; depth of body about 2.8 in standard length; anal soft rays 25; 20 gill rakers on lower portion of first arch (cf., Woods, in Schultz, *et al.*, 1953: 505).

***Caranx ascensionis** (Osbeck)

Fowler and Ball, 1925, 4 specs.

***Caranx dasson** Jordan and Snyder

Fowler and Ball, 1925, 1 spec.

***Caranx gymnostethoides** (Bleeker)

Smith and Swain, 1882, 1 spec.

***Caranx lugubris** Poey

Halstead and Bunker, 1954, 5 specs.

***Caranx melampygus** Cuvier

Halstead and Bunker, 1954, 4 specs.

***Scomberoides sancti-petri** (Cuvier)

Smith and Swain, 1882, 1 spec.; Fowler and Ball, 1925, 2 specs.

Trachurops crumenophthalmus (Bloch)

1 spec., 286 mm., 1951; 4 specs., 121–128 mm., Francis, 1948; 2 specs., 173 and 177 mm., Schaefer, 1948.

Shoulder girdle deeply furrowed.

POMACENTRIDAE

Abudefduf imparipennis (Vaillant and Sauvage)

20 specs., 33–50 mm., 1951. Fowler and Ball, 1925, 4 specs.

Preopercle smooth; teeth flattened at tips; dorsal XII, 15; color plain yellowish green; upper base of pectoral pale.

Abudefduf phoenixensis Schultz

2 specs., 50–51 mm., 1951. As *Abudefduf albofasciatus*, Fowler and Ball, 1925, 2 specs.

Preopercle smooth; teeth somewhat flattened at tips; dorsal XII, 18; anal II, 13; caudal peduncle encircled by a black band, followed abruptly by white on the remainder of the caudal peduncle and tail; a round black spot on the soft dorsal.

***Abudefduf sordidus** (Forskål)

Fowler and Ball, 1925, 8 specs.; Halstead and Bunker, 1954, 7 specs.

Chromis leucurus Gilbert

2 specs., 61 and 65 mm., 1951; 1 spec., 68 mm., Brock, 1948. As *Chromis dimidiatus*, Fowler and Ball, 1925, 1 spec., 64 mm., this specimen reexamined.

This species is described herewith.

After much vacillation, these plain brown-bodied specimens with a black blotch at the pectoral base are here identified as a color

TABLE 2

CERTAIN COUNTS FOR TWO FORMS OF *Chromis leucurus*

FORM	LATERAL LINE SCALES			TOTAL GILL RAKERS					SOFT DORSAL RAYS			SOFT ANAL RAYS			PECTORAL RAYS		
	15	16	17	27	28	29	30	31	12	13	14	12	13	14	16	17	18
Black and white	2	3		1	2	1	1		2	14	2	2	12	4	1	4	
Plain brown	3	2	1	1	2			2		8		1	7		1	2	2

form of the black and white *Chromis leucurus*. Comparison of the same two forms from Hawaiian material provides the following information: (1) the black and white and the brown specimens differ little in morphological features or in counts (Table 2); (2) ripe individuals of both sexes occur in both color forms; and (3), though the two color forms overlap in size ranges, the plain brown form is represented only by specimens 47 to 70 mm. in standard length, whereas black and white specimens range from 17 to 57 mm. In life both forms may be seen over the same coral head. Presumably the brown form represents an ontogenetic color change that occurs after maturity has been attained.

Chromis vanderbilti (Fowler)

1 spec., 35 mm., 1951.

This specimen differs from Hawaiian and Wake Island material in lacking the black on the lower caudal lobe. There appear to be no other differences. Dorsal XII, 11; anal II, 11, the anterior two-thirds black, becoming abruptly light posteriorly.

Dascyllus albisella Gill

12 specs. 43–88 mm., 1951; 2 specs., 69–75 mm., Brock, 1948.

Though no specimens of *Dascyllus trimaculatus* are readily available, the Hawaiian form seems to differ, among other features, in having more dorsal and anal soft rays. The present (1951) specimens agree with the Hawaiian form in having 15 dorsal soft rays in two specimens and 16 in ten, 14 soft rays in the anal of one specimen, and 15 in the anal of eleven.

***Dascyllus marginatus** (Rüppell)

Halstead and Bunker, 1954, 4 specs.

Plectroglyphidodon johnstonianus Fowler

8 specs., 27–80 mm., 1951. Fowler and Ball, 1925, 1 spec. As *Abudefduf johnstonianus*, Halstead and Bunker, 1954, 1 spec.

Lips plicate; dorsal XII, 18; anal II, 16 or 17.

LABRIDAE

***Bodianus bilunulatus** (Lacepède)

As *Harpe bilunulata*, Smith and Swain, 1882, 1 spec.

Cheilinus rhodochrous Günther

3 specs., 146–205 mm., 1951. Halstead and Bunker, 1954, 5 specs. As *Cheilinus digramma*, Smith and Swain, 1882, 3 specs., and Fowler and Ball, 1925, 1 spec.

The 1951 specimens have the elongate head, white band on the caudal peduncle, and IX dorsal spines that seem to characterize this species. No black lines radiating downward from eye.

Epibulus insidiator (Pallas)

9 specs., 73–255 mm., 1951. Fowler and Ball, 1925, 2 specs.; Halstead and Bunker, 1954, 4 specs.

Lower jaw extending backward to isthmus.

***Gomphosus tricolor** Quoy and Gaimard

Fowler and Ball, 1925, 2 specs.

Gomphosus varius Lacepède

16 specs., 27–106 mm., 1951; 4 specs., 27–89 mm., Brock, 1948.

A dark stripe through eye; vertical fins dark.

Halichoeres ornatissimus (Garrett)

1 spec., 58 mm., 1951. Fowler and Ball, 1925, 2 specs., these reexamined.

These specimens all have the characteristic dark mark just behind the eye.

Novaculichthys taeniourus (Lacepède)

1 spec., 119 mm., 1951.

Only four lines radiating out from the eye.

Pseudocheilinus sp.

12 specs., 30–55 mm., 2 specs., 40–46 mm., Brock, 1948.

First dorsal rays usually produced into elongate filaments; two longitudinal scale rows on cheek below eye; three or four black longitudinal lines along upper sides; background color of body bluish; 16 rays in the

pectoral counting the splint above; no black dot on the caudal peduncle above.

This species will be described elsewhere by Dr. L. P. Schultz.

***Pseudocheilinus hexataenia** (Bleeker)

Fowler and Ball, 1925, 6 specs. This record undoubtedly refers to either *Pseudocheilinus* sp. or *P. octotaenia*.

Pseudocheilinus octotaenia (Jenkins)

2 specs., 73 and 85 mm., 1951; 1 spec., 76 mm., Brock, 1948.

First dorsal rays not longer than those of the middle of the fin; three longitudinal rows of scales on cheek below eye; six to eight black longitudinal lines on sides, the lowermost well below the middle of the body; 14 rays in the pectoral fin counting the splint-like ray above.

Stethojulis axillaris (Quoy and Gaimard)

17 specs., 30–71 mm., 1951; 1 spec., 82 mm., Brock, 1948.

One or more black dots along the middle of the caudal peduncle.

Thalassoma ballieui (Vaillant and Sauvage)

Fowler and Ball, 1925, 1 spec. As *Julis verticalis* Smith and Swain, 1882, 1 spec.

Fowler and Ball's specimen has been reexamined. Though in poor condition, it does show the concentration of vertical markings on the scales on the caudal peduncle.

Thalassoma duperrey (Quoy and Gaimard)

16 specs., 55–162 mm., 1951; 1 spec., 146 mm., Brock, 1948. Halstead and Bunker, 1954, 1 spec. As *Julis clepsydralis* Smith and Swain, 1882, 1 spec.

A distinct light brown cross band through shoulder region in life, the fish becoming plain dark in preservative without marks except often for a dark mark on the upper edge of the pectoral base.

Thalassoma lutescens (Lay and Bennett)

5 specs., 53–116 mm., 1951. As *Thalassoma aneitense*, Fowler and Ball, 1925, 1 spec.

This species, of greenish yellow coloration in life, agrees well with Jordan and Evermann's plate (1905, pl. 41, as *T. aneitense*) except that each scale has an indistinct vertical stripe. However, there seems to be no way besides color by which to distinguish these specimens from *T. duperrey*, and it might prove difficult to refute the view that they simply represent a color variant of *T. duperrey* (similar to the yellow phase of *Epibulus insidiator*). The absence of canine teeth given by Jordan and Evermann (*op. cit.*) is valueless. Johnston specimens of *T. lutescens* have canine teeth exactly as in *T. duperrey*.

Thalassoma purpureum (Forskål)

Fowler and Ball, 1925, 1 spec.

This specimen has been reexamined. It has the broad band, branching below, extending

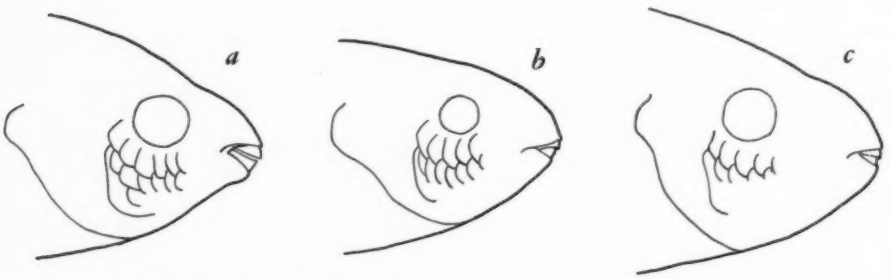

FIG. 2. Heads of species of *Scarus*. *a, Scarus dubius,* from a specimen 4¼ inches in total length with the mouth slightly open and the lips somewhat retracted; *b, Scarus sordidus,* from a 5¾-inch specimen; *c, Scarus perspicillatus,* from a 5½-inch specimen.

down and back from the eye typical of the species.

Thalassoma quinquevittata (Lay and Bennett)

10 specs., 48–110 mm., 1951; 1 spec., 62 mm., Brock, 1948.

Distance from tip of snout to origin of dorsal less than distance from tip of snout to origin of pelvics; a dark band around chin in adults; several dark marks along dorsal base in young.

SCARIDAE

Calotomus sandvicensis (Cuvier and Valenciennes)

7 specs., 90–235 mm., 1951.

The species of *Calotomus*, like those of *Scarus* (see below), are badly confused, and this must be considered a tentative identification.

Genus SCARUS

The present classification of the species of central Pacific parrot fishes is a mess. However, the group is in the process of being monographed (Schultz, ms.). In view of this the aims of the present account are quite limited. They comprise an attempt to separate what seem to be the three commonest species of the genus *Scarus* in Hawaiian waters (which happen to be the three species taken at Johnston) and to see to what extent the green and brown color phases of these species are correlated with sexual differentiation and maturity.

KEY TO THE SPECIES OF *Scarus* COLLECTED AT JOHNSTON ISLAND

1a. Lower (horizontal) limb of preopercular border relatively little developed (Fig. 2*b*, *c*), the length of its free edge (measured to the point at which the border runs vertically) less than the distance from its most anterior point to the midventral line; upper tooth plate never completely covered by the upper lip; pectoral rays usually 14 (not counting the small splint at the top); outline of the border of pelvic fins usually rounded; outer caudal rays never prolonged; canine teeth at the corners of the upper tooth plate, if present, low and knob like . . . **2**

1b. Lower limb of preopercular border relatively well developed (Fig. 2*a*), its length equal to or greater than the distance from its most anterior point to the midventral line; upper tooth plate, when retracted, completely covered by the upper lip; pectoral rays 13 (14 in one out of 14 specimens); pelvic outlines usually pointed between the 1st and 2nd soft rays; caudal truncate in specimens up to 5 inches in total length (Fig. 3*a*, *b*), lunate in larger specimens (Fig. 3*c*) and usually with the outer rays prolonged in fishes between 8.5 inches and the maximum size attained (which is about 12 inches); adults usually with 1 to 3 conspicuous, conical, pointed canines at either side of the upper tooth plate. Two complete scale rows on cheek with sometimes a third incomplete row below (Fig. 2*a*); head of moderate size, less than the greatest depth of body in specimens over 6 inches long . . . . . **dubius**

2a. Lower of the two scale rows on cheek, if present, incomplete, consisting of 1 to 3 scales; head relatively smaller, its length considerably less than the greatest body depth; attains at least 2 feet in length . . . . . **perspicillatus**

2b. Lower of the two scale rows on cheek about as long as the upper, consisting of 5 to 7 scales; head relatively large and bullet shaped, its length about equal to the greatest depth of body; apparently does not reach a length of over 1 foot . . . . . **sordidus**

Scarus dubius (Bennett)

13 specs., 39–162 mm., 1951 (brown form). As *Scarus brunneus*, Halstead and Bunker, 1954, 1 spec.

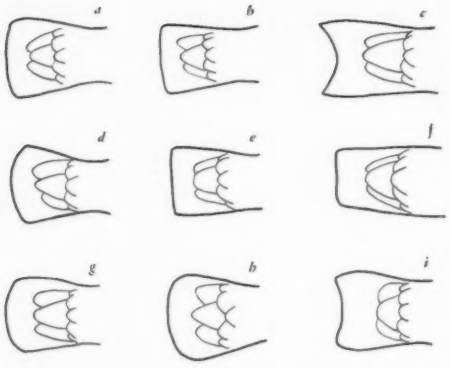

FIG. 3. Caudal fin outlines of *Scarus*. *a–c*, *Scarus dubius*, *a*, 2¾ inches in total length, *b*, 4¼ inches, *c*, 7¾ inches; *d–f*, *Scarus sordidus*, *d*, 3½ inches, *e*, 5¾ inches, *f*, 7 inches; *g–i*, *Scarus perspicillatus*, *g*, 2¾ inches, *h*, 5½ inches, *i*, 12¾ inches.

The rather extensive forward projection of the free preopercular border (Fig. 2*a*) is perhaps the most reliable way of distinguishing the species here tentatively identified as *S. dubius* from the other two species of *Scarus* dealt with here. The following distinguishing features, though helpful, appear to be less reliable. The pectoral rays are usually 13 instead of 14. When the jaws are retracted and the lips are in normal position, the upper lip extends down as a flap over the whole of the upper tooth plate; however, if the jaws are incompletely retracted (even though they may be partially closed as in Fig. 2*a*) or if the lips have been pushed back, the upper tooth plate may protrude. In the other two species the lips never cover the tooth plates except in very small specimens (less than 3 inches in total length). The two, more or less complete scale rows on the cheek will separate *S. dubius* from *S. perspicillatus* but not from *S. sordidus*. Certain features that change with growth are useful in separating *S. dubius* from the other two species if specimens of the same size are compared. Thus *S. dubius* develops a lunate caudal at a length of 7 inches in total length, whereas *S. perspicillatus* does not have a lunate caudal at sizes below 12 inches and *S. sordidus* apparently never does have a lunate caudal. Again, *S. dubius* at a length of perhaps 7 inches usually develops one or two outwardly projecting canines at each corner of the upper jaw, but the other two species apparently never develop these beyond the stage of small, rounded tubercles.

Among the Hawaiian species of *Scarus* for which accounts are given by Jordan and Evermann (1905) the brown form here called *S. dubius* appears to have been included three times: as *Callyodon brunneus* (p. 349), *C. dubius* (p. 350), and as *C. bennetti* (p. 352). These, except for *C. brunneus*, differ in certain details from the form at hand. The major differences judging from Jordan and Evermann's accounts, are as follows: *Callyodon dubius* is said to have 14 pectoral rays; the pectoral count of the present specimens is usually 13. *C. bennetti* is figured with a rounded caudal (but this may be due to the small size of the specimen), the lips are said not to cover the upper jaw, and there are white lines along the scale rows of the lower sides (I have yet to see such markings). Though it is quite possible that more than one species is represented in the above group, a reexamination of Jordan and Evermann's material would be necessary to determine this. Of the three names, *S. dubius* (Bennett) is the oldest. Bennett's original description (1828: 828; type locality Oahu) is very sketchy. However, Günther has redescribed the type, along with other specimens, in two places (1862: 229; 1909: 313). In both of these redescriptions Günther mentions the presence of two scales in a row below the other two cheek rows. The species here dealt with is the only unspotted, brown Hawaiian *Scarus* known to me in which this third row ever occurs.

Scarus dubius apparently does not reach a large size. The largest brown specimen from Johnston is about 8 inches in total length. The largest specimen mentioned in Jordan and Evermann's accounts of *Callyodon brunneus*, *dubius*, and *bennetti* is 9.5 inches.

Of the five individuals more than 6 inches long from Johnston two, 6.4 and 8 inches long, are mature or maturing females. The ovaries are elongate, paired organs without sharp edges and contain small elongate eggs. The three other specimens, 7 to 7.4 inches in total length, contain in the ovarian position and behind the liver, flat, sharp-edged organs. The extent to which these structures are developed in the three individuals varies greatly. At one extreme they are small and leaf like. At the other they are somewhat larger than the largest ovary in the females mentioned above, rather thick, and overlap the intestines at the sides, above, and behind. These large structures must, I think, be identified as ripe testes.

The brown *Scarus dubius*, like the other two species to be dealt with, seems to have a green counterpart. Before discussing this, it seems advisable to say something about green parrot fishes in general based on experience with the scarids in Hawaii and elsewhere. Young parrot fishes, up to about 2 inches in length, are frequently, perhaps always, a plain light green color. These gradually become brownish with growth and I have never seen a green scarid between 3 inches and about 7 inches long. Green parrot fishes (more than 7 inches long) invariably have adult characteristics. In all the three species dealt with here, the size of the green counterpart is comparable to or somewhat larger than the mature brown form. Thus the green counterparts of small brown forms, e.g., *S. dubius* and *S. sordidus*, are always relatively small while those of large brown forms, e.g., *S. ahula* (=*perspicillatus*), are always relatively large. I have never seen a female green scarid, though, as just noted, some brown specimens appear to be adult males. Finally, green parrot fishes seem to be relatively rare as compared with brown individuals, though the distinctiveness in the color markings of the green as contrasted with brown forms has led to the description of numerous green species.

The green counterpart of *S. dubius* is represented in the University of Hawaii collections by four specimens 170 to 190 mm. in total length that died in the Honolulu Aquarium and by one taken at Kailua, Kona, Hawaii. The aquarium specimens are so badly damaged that an exact correspondence in many morphological characters between them and the brown *S. dubius* could not be checked. They do agree in having two scale rows on the cheek, a relatively long horizontal limb to the free preopercular border, 13 pectoral rays, pointed ventrals, and a rather small head. In only two of the four could gonads be found. In these there were relatively small, elongate, sharp edged organs without eggs that must be considered testes.

The 12 inch Kailua specimen is in better condition and hence of greater interest. It is an unripe male; I can only find a testis on the left side. The description of the morphological characters given for the adult brown *S. dubius* fits this specimen completely. The mouth is closed and the upper lip projects forward as a flap over the whole upper tooth plate. The pectoral rays are 13 on each side and there are two complete rows of scales on the cheek. There is a single outwardly-projecting canine on each side of the upper jaw. The caudal is lunate and the outermost soft pelvic ray extends well beyond the others.

Jordan and Evermann (*op. cit.*) recognize six green species of *Scarus* from the Hawaiian islands: "*Callyodon*" *perspicillatus* (p. 347), *C. jenkinsi* (p. 353), *C. gilberti* (p. 354), *C. formosus* (p. 355), *C. lauia* (p. 355), and *C. bataviensis* (p. 356). Of these *Scarus perspicillatus* has the lower row of cheek scales incomplete, and Brock and Yamaguchi (1954: 154) have already demonstrated that it is the adult male of "*S. ahula*." The color description and plate given by Jordan and Evermann for *Scarus lauia* is decidedly dissimilar to that of the specimen at hand and seems to represent an entirely different species. As for the remaining forms: *S. jenkinsi*, *S. gilberti*, *S. formosus*, and *S. bataviensis*, there is nothing in Jordan and Evermann to indicate that any or all of them are

not the species represented by the Kailua specimen. I can see nothing to indicate that this in turn is not an old male of the brown form represented by *S. dubius*. Since *S. dubius* is the oldest name to be applied in either the brown or the green complex dealt with, it may be, at least provisionally, used for this species.

Scarus sordidus Forskål

78 specs., 57–222 mm., 1951 (75 brown, 3 green); 5 specs., 115–175 mm., Brock, 1948. Fowler and Ball, 1925, 2 specs.

This species does not seem to be among those described by Jordan and Evermann and the identification for it was kindly provided by Dr. L. P. Schultz of the U. S. National Museum. It has a characteristic bullet-shaped head and usually has the tooth plates protruding well beyond the lips. These tooth plates are of a dirty, greenish tinge in alcohol. The caudal of this species is rounded in small specimens but truncate in fishes 5.5 inches in total length and larger. It is the most elongate of the three species, and the eye is smaller than in the other two species at the same size. The anal rays are somewhat shorter than in *S. perspicillatus* (longest anal ray contained 1.85–2.34 in anal base of *S. sordidus*, 1.44–1.98 in *S. perspicillatus*). This form often has a white band on the caudal peduncle and there is frequently a black spot in the middle of the band.

It seems to be the commonest scarid at Johnston and not at all infrequent around Oahu. The largest specimen of this brown form taken is about 9 inches long. Most of the specimens more than 5 inches long are mature females with eggs. The ovaries are similar to those of *S. dubius* and are paired in the single specimen checked. Again certain specimens contain the asymetrical, liver-like structure found in the brown form of *S. dubius*. Of a dozen brown specimens checked, one 4.5 inches long was an immature. The rest are larger, the largest being 8.3 inches in total length. Of these, 8 are mature females, and 3 have a large, flattish liver-like organ in the ovarian position. The size of this flattish organ, when present is, in 2 out of the 3 specimens, larger than the largest ovary. This seems peculiar if it is a testis, but repeated attempts to find eggs in it have failed. The facts that the liver is also present in these specimens, that there are no other gonad-like structures along with it, and that it contains no eggs seems to leave little alternative to identifying the structure as a testis despite its size.

Three green specimens, 10.2 to 10.5 inches in total length, were taken with the brown form from Johnston described above. These all duplicate the brown form of *S. sordidus* in morphological characters, e.g., the long head with greatly protruding, greenish tooth plates, the two complete scale rows on the cheek, rounded pelvics, etc. Though the outer caudal rays extend somewhat beyond the inner ones they are not produced as in the green form of *S. dubius*. There are from 0 to 3 small knobs at the sides of the upper jaw; these do not project outward to nearly the extent that they do in adult *S. dubius*. In all of these there is a flat organ on the right side, but in one of the three it does not seem to occur on the left. In this one the organ on the right side is quite small, in the other two of moderate size, considerably smaller than the same organ at its maximum development in the smaller brown form. I think two of the three green specimens may be considered ripe or ripening males and the third an unripe male. In color, these specimens, though faded, differ considerably from the green form of *S. dubius*. The pelvic and caudal coloration is quite plain and that on the head seems to have consisted of broad, indefinite dark bars around the mouth and behind the eye.

Scarus perspicillatus (Steindachner)

5 specs., 72–290 mm., 1951 (4 brown, 1 green). Smith and Swain, 1882, 1 spec.; Halstead and Bunker, 1954, 12 specs. As *Callyodon perspicillatus* Fowler and Ball, 1925, 4

specs. As *Callyodon ahula* Fowler and Ball, 1925, 2 specs.

Since Brock and Yamaguchi have already demonstrated (1954) that the green *S. perspicillatus* is the adult male of the brown *S. ahula*, and since my material adds little to this information, the account of this species may be cut short. Only five specimens of this species were taken at Johnston, four brown and one green. The green specimen, 14 inches in total length, is a ripe male with very large, paired testes. Of the brown form, specimens 4.5 to 9.5 inches in total length are immatures; the other, 14 inches long, is a ripe or ripening female. The large female differs from the ripe male (and from brown specimens of a similar size from Hawaii) in the considerably greater depth of body, but I can see no other characters on which to separate them.

Additional species of *Scarus* recorded from Johnston are:

***Scarus cyanogrammus** (Jordan and Seale)
Halstead and Bunker, 1954, 1 spec.

***Scarus duperrey** (Quoy and Gaimard)
Halstead and Bunker, 1954, 1 spec.

***Scarus erythrodon** Cuvier and Valenciennes
As *Callyodon erythrodon*, Fowler and Ball, 1925, 4 specs.

***Scarus forsteri** Valenciennes
Halstead and Bunker, 1954, 1 spec.

CHAETODONTIDAE

Centropyge flammeus Woods and Schultz
4 specs., 70–81 mm., 1951. Woods and Schultz, in Schultz, *et al.*, 1953, 6 specs. As *Holacanthus loriculus*, Fowler and Ball, 1925, 1 spec.

***Centropyge nigriocellus** Woods and Schultz
Woods and Schultz, in Schultz, *et al.*, 1953, 1 spec.

Chaetodon auriga Forskål
14 specs., 112–145 mm., 1951; 1 spec., 117 mm., Schaefer, 1948. Halstead and Bunker, 1954, 7 specs. As *Chaetodon setifer*, Smith and Swain, 1882, 1 spec. and Fowler and Ball, 1925, 5 specs.

Chaetodon citrinellus Cuvier
5 specs., 92–100 mm., 1951. Halstead and Bunker, 1954, 1 spec.

Chaetodon ephippium Cuvier
2 specs., 124 and 158 mm., 1951. Fowler and Ball, 1925, 1 spec.; Halstead and Bunker, 1954, 2 specs.

Chaetodon multicinctus (Garrett)
3 specs., 86–89 mm., 1951. As *Chaetodon punctatofasciatus*, Fowler and Ball, 1925, 3 specs. and Halstead and Bunker, 1954, 2 specs.

This species is dealt with briefly in section 2.

Chaetodon ornatissimus Solander
4 specs., 110–147 mm., 1951. Fowler and Ball, 1925, 3 specs.; Halstead and Bunker, 1954, 4 specs.

Chaetodon quadrimaculatus Gray
2 specs., 108 and 108 mm., 1951. Fowler and Ball, 1925, 3 specs.

Chaetodon trifasciatus Mungo Park
Fowler and Ball, 1925, 5 specs. Determination checked.

Chaetodon unimaculatus Bloch
3 specs., 82–88 mm., 1951; 1 spec., 41 mm., Brock, 1948. Fowler and Ball, 1925, 6 specs.

***Megaprotodon strigangulus** (Gmelin)
Halstead and Bunker, 1954, 1 spec.

ZANCLIDAE

Zanclus cornutus Cuvier
1 spec., 98 mm., 1951. Halstead and Bunker, 1954, 1 spec. As *Zanclus canescens*, Fowler and Ball, 1925, 2 specs.

ACANTHURIDAE

Acanthurus achilles Shaw
18 specs., 114–210 mm., 1951. Halstead

and Bunker, 1954, 4 specs. As *Hepatus achilles*, Fowler and Ball, 1925, 3 specs.

Acanthurus elongatus (Lacepède)

54 specs., 80–126 mm., 1951. Halstead and Bunker, 1954, 13 specs. As *Hepatus lineolatus*, Fowler and Ball, 1925, 5 specs.

A small dark spot at the base of the last dorsal and anal rays.

Acanthurus olivaceus Schneider

1 spec., 200 mm., 1951. Halstead and Bunker, 1954, 6 specs. As *Hepatus olivaceus*, Fowler and Ball, 1925, 1 spec.

Fowler and Ball record 3 specimens of *Hepatus nigricans* from Johnston; one of these is in the Bishop Museum and is *Acanthurus olivaceus*.

Acanthurus sandvicensis Streets

21 specs., 63–127 mm., 1951. As *Acanthurus triostegus*, Smith and Swain, 1882, 2 specs. and Halstead and Bunker, 1954, 5 specs.; as *Hepatus sandvicensis*, Fowler and Ball, 1925, 7 specs.

This species will be treated in section 2.

***Ctenochaetus striatus** (Quoy and Gaimard)

Halstead and Bunker, 1954, 7 specs.

Ctenochaetus strigosus (Bennett)

11 specs., 72–106 mm., 1951; 1 spec., 80 mm., Brock, 1948. Fowler and Ball, 1925, 1 spec.

These specimens are included in Randall's report on the genus which is in press.

Naso lituratus (Schneider)

5 specs., 152–210 mm., 1951. Halstead and Bunker, 1954, 7 specs. As *Naseus lituratus*, Smith and Swain, 1882, 2 specs.; as *Acanthurus lituratus*, Fowler and Ball, 1925, 4 specs.

Zebrasoma flavescens (Bennett)

1 spec., 54 mm., 1951. Fowler and Ball, 1925, 3 specs.; Halstead and Bunker, 1954, 1 spec.

Plain yellow in color.

ELEOTRIDAE

Eviota viridis (Waite)

Fowler and Ball, 1925, 3 specs.

These specimens have been reexamined, but are in too poor condition to provide a definite identifcation.

GOBIIDAE

***Bathygobius fuscus** Rüppell

Fowler and Ball, 1925, 4 specs.

There seems no reason to doubt the original determination.

Gnatholepis anjerensis (Bleeker)

5 specs., 19–34 mm., 1951.

Tongue strongly bilobed; anal with 11 soft rays in all 5 specimens.

Zonogobius farcimen (Jordan and Evermann)

5 specs., 16–22 mm., 1951.

These specimens agree well with the description and figure of this species by Jordan and Evermann (1905).

BLENNIIDAE

Cirripectus variolosus (Valenciennes)

52 specs., 24–63 mm., 1951; 2 specs., 55 and 59 mm., Brock, 1948. As *Rupiscartes variolosus*, Fowler and Ball, 1925, 22 specs.

Body plain; nuchal cirri totaling 36 in one specimen; first dorsal rays elongate.

Exallias brevis (Kner)

1 spec., 46 mm., Brock, 1948.

A broad fleshy flap on either side of the chin; scattered reddish spots on the head, body, and fins.

Salarias gibbifrons (Quoy and Gaimard)

17 specs., 23–73 mm., 1951. As *Rupiscartes gibbifrons*, Fowler and Ball, 1925, 1 spec.

Long, simple, slender cirri over eye; middle of eye about over front of upper jaw; a spot between the first two dorsal spines.

BROTULIDAE

Brotula townsendi Fowler

1 spec., 127 mm., 1951.

This specimen has been reported on previously (Gosline, 1953).

MUGILIDAE

Neomyxus chaptalii (Eydoux and Souleyet)
1 spec., 286 mm., 1951. Fowler and Ball, 1925, 5 specs.
Forty-four scales in a longitudinal series.

SPHYRAENIDAE

***Sphyraena japonica** (Cuvier)
Fowler and Ball, 1925, 3 specs.

POLYNEMIDAE

***Polydactylus sexfilis** (Cuvier and Valenciennes)
As *Polynemus kuru*, Smith and Swain, 1882, 1 spec.

SCORPAENIDAE

Scorpaenids seem to be rare around Johnston, and the only two species taken are the two that are perhaps commonest around Hawaii. They are not difficult to separate but they have been badly confused. Nomenclatorially the difficulty starts at the generic level. Jordan and Evermann (1905) have placed the two in *Sebastapistes*. Schultz (1943), for reasons which are not clear, divides the members of *Sebastapistes* between *Scorpaenopsis* and *Scorpaena*. Matsubara (1943), who will be followed here, places all of *Sebastapistes* back under *Scorpaena*.

At the specific level a nomenclatorial problem also arises. The oldest name for any Hawaiian species is *Scorpaena asperella* Bennett (1828). The description of this species, based on a single specimen 2 inches long, gives almost no morphological characters of any value, and the coloration does not agree very well with anything subsequently found in the Hawaiian Islands. The type, according to Günther (1873: 80), has been lost. The name *Scorpaena asperella* has been applied in various ways. Günther (1860: 107) considered the species unrecognizable. Jordan and Evermann (1905) thought that the description applied to some Hawaiian species that they did not have. This seems rather unlikely, for of the 11 Hawaiian species described by Bennett 9 of the names have subsequently been identified among the most common of small inshore fishes and the other 2 have never been identified very satisfactorily with anything. One suspects that the difficulty with these 2 lies not in the rarity of the species described but in the nature of Bennett's descriptions. In 1943 Schultz (p. 172) applied the name to a species from Samoa.

I have repeatedly compared Bennett's description with small scorpaenids from Hawaii and can only conclude that it checks about as well (or as badly) with one as with another. Under the circumstances it seems best to follow Günther's usage in considering the name unrecognizable.

The following tabulation of characteristics will serve to distinguish the two species of *Scorpaena* collected at Johnston:

Eight spines on the top of the head above and behind the orbital rim, the front four in a transverse row; pectoral base without scaly sheath; cheek and opercle naked; pectoral with 4 branched rays; suborbital with a single blunt, backwardly projecting knob; no distinct, small dark spots; a black blotch usually present on the posterior part of the spinous dorsal in specimens more than 3 inches long; last dorsal ray attached for most of its length to the caudal peduncle by means of a membrane . . . . . **S. ballieui**

Six spines on the top of the head above and behind the orbital rim; pectoral with a scaly sheath at base that extends well out onto the pectoral fin; cheek and opercle scaled; pectoral with 5 branched rays; suborbital with two divergent, backwardly projecting points; small, distinct dark spots on and below the base of the dorsal fin, on the head, and in the pectoral axil; no black

blotch on the posterior part of the spinous dorsal; last dorsal ray attached to the caudal peduncle for less than half its length..... .....**S. coniorta**

Five species of *Sebastapistes* from Hawaii are recognized by Jordan and Evermann (1905: 455–460), and a sixth is described from deeper water by Gilbert (1905: 627). Of these *S. asperella*, as noted above, must apparently be considered unidentifiable. Of the others, *S. coniorta* seems to apply to the scaled-cheek species. Judging from Jordan and Evermann's descriptions, *S. balieui*, *S. corallicola*, and probably *S. galactacma* belong with the naked-cheeked species. *S. coloratus* appears to represent a third species.

At present it seems best to designate the two Johnston species as *Scorpaena ballieui* Sauvage and *S. coniorta* (Jenkins). Other related species have been described from elsewhere in the tropical Indo-Pacific, but in the absence of comparative material it is impossible to determine which of these are the same as the two Johnston species and which are different.

Scorpaena ballieui Sauvage
1 spec., 23 mm., 1951.

Scorpaena coniorta (Jenkins)
1 spec., 51 mm., 1951.

BOTHIDAE

Bothus mancus (Broussonet)
1 spec., 160 mm., 1951. Halstead and Bunker, 1954, 2 specs. As *Platophrys mancus*, Smith and Swain, 1882, 1 spec. and Fowler and Ball, 1925, 3 specs.
Dorsal 96; anal 78.

ECHENEIDAE

Remora remora (Linnaeus)
1 spec., 67 mm. from shark taken outside reef.
Pelvic fins with their inner rays attached to the abdomen for most of their length; laminae 17; lower jaw greatly exceeding upper in length.

BALISTIDAE

Melichthys buniva (Lacepède)
9 specs., 155–185 mm., 1951. Fowler and Ball, 1925, 3 specs. As *Balistes buniva*, Smith and Swain, 1882, 3 specs.
Dorsal and anal black with a narrow blue line at base. A very common species, which seemed to be thriving on the garbage periodically dumped into the lagoon at the time we were there.

***Melichthys ringens** (Osbeck)
Halstead and Bunker, 1954, 11 specs.

Melichthys vidua (Solander)
1 spec., 150 mm., 1951. Halstead and Bunker, 1954, 2 specs. As *Balistes vidua*, Fowler and Ball, 1925, 2 specs.
Dorsal and anal light except for the narrow dark borders. Fraser-Brunner's placement (1935: 662) of this species in the genus *Melichthys* seems questionable.

Rhinecanthus aculeatus (Linnaeus)
Halstead and Bunker, 1954, 3 specs. As *Balistes aculeatus*, Smith and Swain, 1882, 2 specs. and Fowler and Ball, 1925, 1 spec. (this record checked).
Three longitudinal rows of black spinelets on the caudal peduncle.

MONACANTHIDAE

***Amanses carolae** (Jordan and McGregor)
Halstead and Bunker, 1954, 2 specs.

Amanses sandwichiensis (Quoy and Gaimard)
3 specs., 140–270 mm., 1951. Halstead and Bunker, 1954, 1 spec. As *Monacanthus sandwichiensis*, Fowler and Ball, 1925, 1 spec.
The 140 mm. specimen has no spines on the caudal peduncle; the two larger (190 and 270 mm.) have 4 forwardly projecting spines in two rows on each side.

Pervagor melanocephalus (Bleeker)
3 specs., 82–106 mm., 1951. As *Monacanthus melanocephalus*, Fowler and Ball, 1925, 4 specs.

Dorsal rays 32 in one specimen.

OSTRACIONTIDAE

***Kentrocarpus hexagonus** (Thunberg)
Halstead and Bunker, 1954, 1 spec.

***Ostracion cubicus** Linnaeus
Halstead and Bunker, 1954, 1 spec.

Ostracion lentiginosum Schneider
15 specs., 76–126 mm., 1951. Fowler and Ball, 1925, 3 specs. As *Ostracion punctatum*, Smith and Swain, 1882, 1 spec.

***Ostracion meleagris** Shaw
Halstead and Bunker, 1954, 9 specs.

Ostracion solorensis Bleeker
Fowler and Ball, 1925, 1 spec.

This specimen has the upper sides with alternating brown and white stripes, the brown ones continuous but the white ones broken up into segments. Below the banded area the body is abruptly light. A very slight dorsal ridge just ahead of dorsal fin; ventrolateral ridges expanded into laminae. Carapace closed over behind the dorsal and anal fins to form two horizontal laminae. Supraorbital ridges somewhat raised and rough. No spines anywhere.

TETRAODONTIDAE

Arothron meleagris (Lacepède)
2 specs., 140 and 160 mm., 1951. Halstead and Bunker, 1954, 1 spec. As *Tetraodon meleagris*, Smith and Swain, 1882, 3 specs., Fowler and Ball, 1925, 4 specs.

Head, body, and fins with small light spots on a dark ground. Outer portions of fins, except caudal, light.

CANTHIGASTERIDAE

Canthigaster jactator (Jenkins)
3 specs., 40–64 mm., 1951; 1 spec., 52 mm., Brock, 1948. Halstead and Bunker, 1954, 1 spec.

Round white spots on a dark ground.

DIODONTIDAE

***Diodon hystrix** Linnaeus
Smith and Swain, 1882, 1 spec.

SECTION 2. THE NATURE AND RELATIONSHIPS OF THE JOHNSTON ISLAND FISH FAUNA

Johnston Island is one of the more isolated of Pacific atolls. It is separated by some 450 miles of deep water from the nearest reef area, French Frigate Shoals in the Hawaiian chain to the north (see Fig. 1). To the south and east the nearest shoal water (Kingman Reef in the Line Islands) is about 700 miles away, whereas the closest land to the west is in the Marshalls perhaps 1300 miles distant.

The position of Johnston Island poses two principal questions for the zoogeographer: (1) to what extent does its isolation give rise to endemism, and (2) to what extent has Johnston acted as a stepping stone or filter bridge between the Hawaiian biota and that of the Line Islands to the south. An attempt to answer these two questions constitutes the present section of this paper.

Before proceeding it seems well to define certain terms that will be used here. "Central Pacific" will be employed in a zoogeographic sense to refer to a faunal area whose limits are unknown but which includes the Line, Phoenix, Gilbert, and Marshall islands but *not* Johnston and the Hawaiian chain. "Hawaiian" used zoogeographically will refer to the inshore marine fauna of the Hawaiian chain together with that of Johnston. "Hawaii" used geographically generally refers to the Hawaiian chain of islands, though the fact that the largest island in this chain is also called Hawaii is admittedly confusing.

The question of endemism among Johnston fishes is easily dealt with and dismissed. Only two species of Johnston fishes have not been taken elsewhere—*Centropyge nigriocellus* and *C. flammeus*. Neither of these is abundant at Johnston (the former is known only from one specimen), and it may well be that they merely

remain uncollected elsewhere. In a few other fishes the Johnston specimens seem somewhat aberrant but probably do not deserve recognition as separate species. The principal significance of this low degree of endemism at Johnston lies in the demonstration that for Pacific island fishes 450 miles of open water without strong current systems has not resulted in much differentiation.

The problem of evaluating Johnston as a filter bridge is far more complex. The present attack on it is divided into two facets. The first approaches the problem in terms of the relative strengths of the various components of the Johnston shallow-water fish fauna. The objective here is to obtain a general picture of the relationships of the fish fauna of Johnston Island. The second deals in greater detail with certain Johnston fishes that are represented by different geographic forms south of the island than occur to the north. Its objective is to trace, in so far as possible, individual migration routes.

Components of the Johnston Fish Fauna

For purposes of the faunal analysis that follows, certain families of fishes have been excluded for one reason or another. First, those fishes that are pelagic or semipelagic as adults are omitted. For these, Johnston may have no significance whatever as a way point, and to include them would only obscure the data. Groups excluded from consideration for this reason are the sharks and rays, the needle fishes, half-beaks, flying fishes, carangids, barracudas, tunas, remoras, and all fishes taken from over 100 feet of water. Second, the parrot fishes and scorpaenids have also been excluded, but for the reason that at the present time they are so confused taxonomically as to make species records worthless zoogeographically. Finally, the species recorded from Johnston by Halstead and Bunker (1954) only will not be considered as I have not been able to check their records. Fowler and Ball's (1925) species have, on the other hand, been included because, as already mentioned, material upon which their more questionable identifications were based have been reexamined. Following is the reduced list of Johnston species, upon which the following analysis is based.

SPECIES CONSIDERED IN THE ANALYSIS OF THE JOHNSTON FISH FAUNA

Central Pacific Species Reaching Johnston but Not Hawaii (Group B of Fig. 4)

Leptenchelys labialis
Muraenichthys gymnotus
Muraenichthys schultzei
Brachysomophis sauropsis
Myrichthys bleekeri
Echidna leucotaenia
Uropterygius polyspilus
Kuhlia marginata
Parupeneus barberinus
Abudefduf phoenixensis
Epibulus insidiator
Thalassoma quinquevittata
Pervagor melanocephalus
Ostracion solorensis

Species Endemic to Johnston (Group G of Fig. 4)

Centropyge flammeus
Centropyge nigriocellus

Hawaiian Species Reaching South to Johnston but Not Beyond (Group E of Fig. 4)

Muraenichthys cookei
Gymnothorax eurostus
Uropterygius dentatus
Apogon menesemus
Apogon waikiki
Parupeneus multifasciatus
Cirrhitus alternatus
Chromis leucurus
Chromis vanderbilti
Dascyllus albisella
Halichoeres ornatissimus
Thalassoma ballieui
Thalassoma duperrey
Chaetodon multicinctus
Acanthurus sandvicensis
Zonogobius farcimen

Johnston Species Found Both in Hawaii and in the Central Pacific (Group C of Fig. 4)

Saurida gracilis
Synodus binotatus
Conger noordziekii
Leiuranus semicinctus
Myrichthys maculosus
Schultzidia johnstonensis
Moringua macrochir
Anarchias allardicei
Anarchias cantonensis
Anarchias leucurus
Echidna polyzona
Echidna zebra

Gymnothorax gracilicauda
Gymnothorax meleagris
Gymnothorax moluccensis
Gymnothorax pictus
Gymnothorax undulatus
Rabula fuscomaculata
Uropterygius fuscoguttatus
Uropterygius tigrinus
Aulostomus chinensis
Fistularia petimba
Holocentrus tiere
Holocentrus microstomus
Holocentrus lacteoguttatus
Holocentrus sammara
Holocentrus spinifer
Holotrachys lima
Myripristis argyromus
Apogon erythrinus
Apogon snyderi
Pseudamiops gracilicauda
Pseudogramma polyacanthus
Priacanthus cruentatus
Kyphosus vaigiensis
Mulloidichthys auriflamma
Mulloidichthys samoensis
Parupeneus bifasciatus
Parupeneus chryserydros
Parupeneus pleurostigma
Paracirrhites bimacula
Abudefduf imparipennis
Abudefduf sordidus
Plectroglyphidodon johnstonianus
Bodianus bilunulatus
Cheilinus diagrammus
Cheilinus rhodochrous
Gomphosus tricolor
Gomphosus varius
Novaculichthys taeniourus
Pseudocheilinus sp.
Pseudocheilinus octotaenia
Stethojulis axillaris
Thalassoma lutescens
Thalassoma purpureum
Chaetodon auriga
Chaetodon citrinellus
Chaetodon ephippium
Chaetodon ornatissimus
Chaetodon quadrimaculatus
Chaetodon trifasciatus
Chaetodon unimaculatus
Zanclus cornutus
Acanthurus achilles
Acanthurus elongatus
Acanthurus olivaceus
Ctenochaetus strigosus
Naso lituratus
Zebrasoma flavescens
Bathygobius fuscus
Gnatholepis anjerensis
Exallias brevis
Cirripectus variolosus
Salarias gibbifrons
Brotula townsendi
Neomyxus chaptalii
Polydactylus sexfilis
Bothus mancus
Rhinecanthus aculeatus
Melichthys buniva
Melichthys vidua
Amanses sandwichiensis
Ostracion lentiginosum
Arothron meleagris
Canthigaster jactator
Diodon hystrix

For purposes of assessing the importance of Johnston as a filter bridge for species coming up from the south the following groupings have been made (see Fig. 4): (A) those fishes that never reached Johnston, (B) those that got to Johnston but no farther, (C) those that apparently passed through Johnston on the way from the Line Islands to Hawaii or vice versa, and (D) those that apparently by-passed Johnston. Similarly, the Hawaiian species may be divided into (F) those that never reached Johnston, (E) reached Johnston and stopped, (C) passed through Johnston, and (D) by-passed Johnston.

The stringency of the Johnstonian filtering effect on northbound and on southbound fishes will be shown by the relative strengths of each of the above categories (except D). An attempt to quantify each of these relative to one another is therefore made in Figure 4 by means of the widths of the columns. Widths of columns B, C, E, and G are based directly on the relative number of Johnston species in each of these categories in the list. Column D is given no width, because it is impossible to know how much of column D is represented but as yet uncollected at Johnston. Widths for A and F were estimated in a very simple and admittedly imperfect fashion, and indicate only rough magnitudes. Two shallow-water poison stations run at Palmyra, the nearest island to the south of Johnston, by Mr. J. E. King, *et al.*, in approximately the same way as those made at Johnston yielded (among the same fish groups used here) 62 species of which 29 are not known from Johnston or Hawaii. Thus, the number of species in these two collections (and pre-

sumably in the Palmyra inshore fish fauna as a whole) that does not get north is calculated as 29/33 of the number that does. Consequently column A is assigned a width slightly less than the combined widths of B and C, which had been calculated previously. Similarly, the width of F is based on an inshore Oahu rotenone station from which 69 species in the same groups were collected. Of these, 17 do not get as far south as Johnston. Hence F is assigned a width about one third (actually 17/52) of the combined widths of C and E.

The fact that there are 16 Hawaiian species found at Johnston but not, apparently, farther south and 14 Central Pacific species that get to Johnston but not farther north indicates that at the present time Johnston is acting as a filter bridge for fishes passing in both directions. The nature of the filtering effect on northbound and on southbound species must now be considered.

Starting at the south, a very large component of the two poison stations run at Palmyra (29 of 52 species) is not known in Johnston or Hawaii. Two very striking members of this component are the genera *Lutjanus* and (except for a single species) *Epinephelus*. One immediately wonders if these fishes never got to the northern islands or whether they got there but have been unable to survive there because of unsuitable ecological conditions. If the latter were correct, one would suspect the colder water temperatures in the north to be either the direct or indirect cause of the unsuitability. There are certain indications that distance rather than water temperature has been the primary cause in preventing Central Pacific species from reaching Johnston and Hawaii. One of these is provided by the fishes of Japan. The southern Japanese Islands are separated by no such deep-water distances from tropical Pacific islands as Johnston is from Palmyra, but surface water temperatures in southern Japan are at least as cold as those of the Hawaiian Islands (Sverdrup, Johnson, and Fleming, 1946: charts II and III, and fig. 32B). Nevertheless, 15 species of *Epinephelus* (Tanaka, 1931: 26) and 14 species of *Lutjanus* (Kamohara, 1954: 114) are recorded from Japan. This suggests that the Hawaiian water temperatures would not be unsuitable for at least some species of *Lutjanus* and *Epinephelus*. An attempt to find an area separated from the tropical Pacific by a deep-water barrier as great as that isolating the Hawaiian Islands and Johnston leads to an examination of the tropical American data. Snodgrass and Heller (1905: 338) list some 13 species of inshore tropical Pacific species as occurring in the islands of the west coast of the Americas. Of these, none belong to the genera *Lutjanus* or *Epinephelus* or to any of the other species that are not represented at Johnston and Hawaii. To state this last matter positively, all 13 have representatives in the Hawaiian Islands today. These two straws in the wind indicate that the great diminution in species between Palmyra and Johnston is caused primarily by (deep-water) distance rather than by temperature. Such a distance effect could, of course, be either primary or secondary. If primary, the fishes themselves have been unable to get to Johnston; if secondary, the fishes may have been able to get there but the organisms they depend upon for a livelihood have not. Though there is no way of determining which of these two possibilities has been realized, it seems improbable that such unspecialized carnivorous genera as *Lutjanus* and *Epinephelus* would have found the food supply inadequate, had they arrived there.

Of those tropical fishes that have reached Johnston, the great majority seem to have passed on through to Hawaii. There are, however, 14 species that are not known north of Johnston. Some of these, e.g., *Epibulus insidiator*, are quite striking members of the tropical Pacific fauna, and it seems improbable that they should go unrecorded in the Hawaiian fauna if they exist there. One suspects that the reason they have not crossed the minor water gap between Johnston and

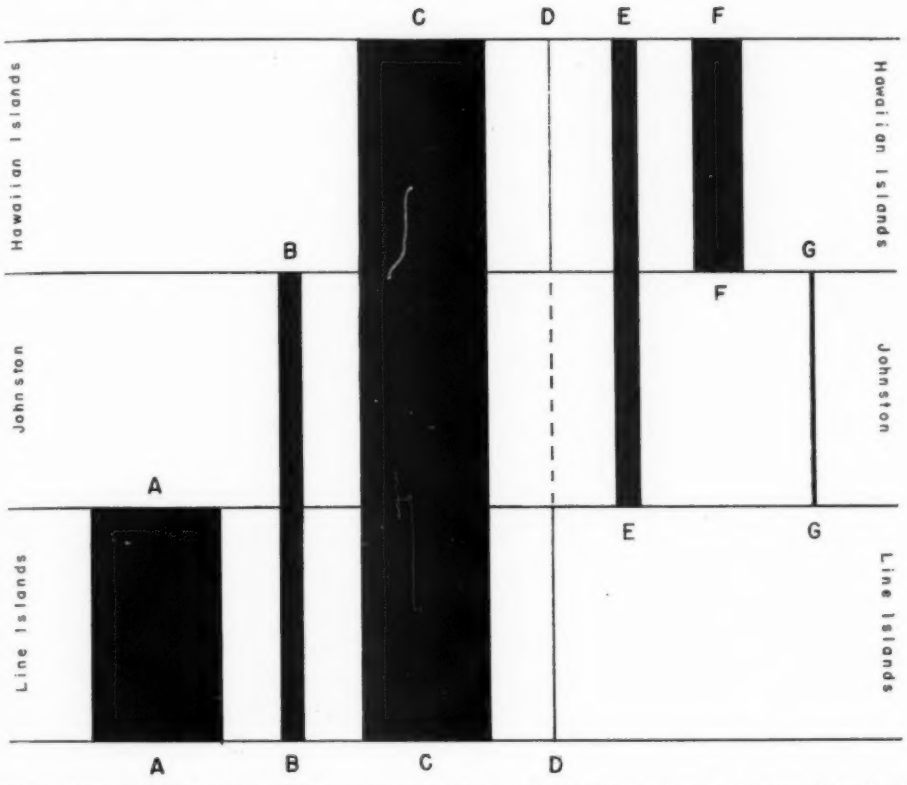

FIG. 4. Diagram of the zoogeographic components making up the inshore fish fauna of Johnston Island and the island chains nearest to Johnston. A, that portion of the Line Island fauna that does not reach Johnston or the Hawaiian Islands; B, that portion of the Line Island fauna that reaches to Johnston but not to the Hawaiian Islands; C, the component that is held in common by the Line Islands, Johnston, and the Hawaiian Islands; D, the component that is common to the Line and Hawaiian Islands but has not, up to now, been recorded from Johnston; E, that portion of the Hawaiian fauna that has reached Johnston but not farther south; F, the portion of the Hawaiian fauna that is restricted to the Hawaiian chain; and G, the component restricted to Johnston Island. Widths of the bars, except D, represent the relative strengths of the various components; for the way in which these widths were calculated, see text.

Hawaii after hurdling the major one between Palmyra and Johnston is that the ecological conditions in Hawaii are not suitable to them. This is of course merely a guess, but it may be noted that the Johnston coral reefs, made up as they are to a considerable extent of *Acropora*, would seem to form a quite different environment from the Hawaiian reefs, where *Acropora*, amongst other elements, is lacking. To bulwark this point further it may be noted that certain rather prominent components of the tropical Pacific fauna that do reach Hawaii are rare there and apparently do not find the environment particularly suitable. In this category belong such species as *Gymnothorax pictus*, *Holocentrus microstomus*, *Thalassoma lutescens*, *Chaetodon citrinellus*, *Chaetodon ephippium*, *Pomacanthus imperator*, and *Acanthurus aliala*.

Summing up for the "northbound" fishes

it appears that: (1) close to a half of the Line Island inshore fish fauna does not occur in Johnston or Hawaii and that the principal reason for this is the great area of deep water between the northernmost Line Island reef and Johnston; (2) the majority of tropical Pacific fishes that have reached Johnston also occur in Hawaii; (3) the relatively few species of tropical Pacific fishes that are known from Johnston but not Hawaii may have reached but have not survived in the latter islands because of differences in ecological conditions between Johnston and the Hawaiian chain.

What may be termed the southbound fishes are now up for discussion. In the first place it must be noted that there is a very much smaller proportion of the Hawaiian inshore fishes restricted to the Hawaiian Islands (F of Fig. 4) than of tropical Pacific fishes that do not get north from the Line Islands (A of Fig. 4). Indeed, it is quite certain that there is a considerably smaller number of Hawaiian "endemics" with the potentialities for moving south than of tropical Pacific fishes that might move north. Of the former group a rather high percentage (though a low number of species) have reached Johnston. It is for this reason that Johnston is to be considered primarily as an outlier of the Hawaiian faunal region rather than as a part of the tropical Central Pacific fauna. The example drawn from the Palmyra and Hawaiian poison stations will bring out this point. In the Hawaiian rotenone station of 69 species, only 17 are restricted to Hawaii, but another 4 are restricted to Hawaii and Johnston. In the Palmyra poison stations of 62 species, 29 are not known north of Palmyra but only 1 is known from Palmyra and Johnston but not Hawaii. On the basis of these figures (fishes found both in Hawaii and Palmyra being excluded) the Johnston inshore fauna is 4/17 Hawaiian and 1/29 tropical Pacific. To what extent other Hawaiian endemics will turn up at Johnston remains to be seen.

Finally, it is necessary to say something of those fishes found today in Hawaii, Johnston, and the tropical Pacific (C of Fig. 4). First, it seems certain that as more attention is given to the fishes in this category more of them will prove to show differentiation between the Hawaiian and Line Islands. Meanwhile there is no sure way of telling whether this group has moved north or south via Johnston. However, certain points regarding the hypothesis of Johnston as the original port of entry for the Hawaiian fauna may be mentioned. On the one hand, it is certain that the Hawaiian inshore fish fauna was ultimately derived from that of the tropical Pacific. Further, there is no island that could or does at the present time provide a better stepping stone between the Hawaiian chain and the tropical Pacific fauna. Finally it has been indicated above that Johnston does at the present time serve as a terminal point for at least some northward movement. On the other hand, the age of Johnston is unknown, and it may be that Johnston is younger than the Hawaiian fish fauna as we know it at present. If this were so, it would be far easier to explain why the following Hawaiian representatives of tropical Pacific forms rather than the latter forms themselves are present at Johnston: *Muraenichthys cookei*, *Gymnothorax eurostus*, *Cirrhitus alternatus*, *Chromis leucurus*, *Chaetodon multicinctus*, and *Acanthurus sandvicensis*. Because of these features it seems best not to make categorical statements as to whether (or how much of) the Hawaiian fish fauna did or did not originally enter via Johnston. It can, however, be stated that a more plausible port of entry has yet to be found.

Analysis of Individual Species

The individual species investigated here are Johnston fishes represented by different geographic variants in the Central Pacific and in the Hawaiian chain. They do not include all fishes in this category but only those for which sufficient information is available to be worth discussing. The following species complexes will be dealt with (in each pair the Hawaiian form is mentioned first): *Murae-*

nichthys cookei–laticaudata, *Gymnothorax eurostus–buroensis*, *Kuhlia sandvicensis–marginata*, *Cirrhitus alternatus–pinnulatus*, *Chaetodon multicinctus–punctato-fasciatus*, and *Acanthurus sandvicensis–triostegus*. A uniform treatment for all six species would be desirable in order to enable comparison of all six area by area. Unfortunately the availability of specimens makes this impossible.

Before these species are dealt with, it seems advisable to provide certain background information. The Johnston collections were originally made to check whether the endemic Hawaiian fishes were really species or merely subspecies. It was felt that intergradation between the Hawaiian endemics and their Central Pacific counterparts would occur at Johnston if anywhere. It does not occur there (or elsewhere) among any of the fishes here investigated, and on the basis of absence of intergradation (the term is here used in contrast with introgression) the Hawaiian endemics must be considered full species. But would the Hawaiian endemics interbreed with their Central Pacific counterparts if both were present? There is no way of determining this at Johnston, because the two never occur together there (or elsewhere). When a Central Pacific fish is represented by a variant in Hawaii, either the Central Pacific form (e.g., *Kuhlia marginata*) or the Hawaiian form (e.g., *Muraenichthys cookei*, *Gymnothorax eurostus*, *Cirrhitus alternatus*, *Chaetodon multicinctus*, and *Acanthurus sandvicensis*), or neither, but not both, occurs at Johnston. That this proves nothing regarding the interbreeding potentialities of the two geographic forms has been discussed in an earlier paper (Gosline, In press). The failure to be able to determine whether interbreeding between the Hawaiian endemics and their Central Pacific counterparts would or does occur makes it impossible to prove whether the Hawaiain forms are full species or merely subspecies. This matter has also been discussed elsewhere (Gosline, *op. cit.*). The point here is that the failure to settle the matter has led to considerable zoogeographic misunderstanding concerning endemism in the Hawaiian inshore fish fauna. For example, Jordan and Evermann (1905: 32) conclude that about 50 per cent of the species of Hawaiian shallow water fishes are endemic; Fowler's (1928) treatment of the same fishes would give a far lower percentage of endemism, perhaps 15 per cent. This appears to be a disagreement concerning the number of endemic Hawaiian fishes, but in reality it is a difference in viewpoint regarding how many Hawaiian endemics should be treated as full species. That one viewpoint is correct and the other incorrect will probably never be proved. About all that can be said is that in general the Hawaiian offshoots of Indo-Pacific species are more distinctive than those that occur anywhere else. Since I believe that Jordan and Evermann's interpretation of Hawaiian endemism in fishes brings out this point more clearly than Fowler's and since no real intergradation can be demonstrated between Hawaiian and Central Pacific forms, it seems preferable to side with Jordan and Evermann.

Muraenichthys cookei–laticaudata

The Hawaiian form, *Muraenichthys cookei*, was described by Fowler (1928: 41, fig. 9). In 1943 Schultz (p. 53) synonymized Fowler's species with *Muraenichthys laticaudata* (Ogilby) described from Fiji. In 1949 Schultz and Woods (p. 172) recognized both species, differentiating them on the basis of the more anterior position of the dorsal origin in relation to the anus in *M. cookei*. The same basis of differentiation is used by Schultz (in Schultz, *et al.*, 1953: 72–73). No other differences between the two species are known. The relationship between the dorsal origin and the anus in specimens of the *M. cookei–laticaudata* complex from several localities is shown in Table 3. (In the table total lengths have not been given since there is no evidence of a change in the dorsal–anus relationship with growth.) Several points can only be suggested by this table since the within-sample variabil-

TABLE 3

THE RELATIONSHIP BETWEEN THE DORSAL ORIGIN AND THE POSITION OF THE ANUS IN SPECIMENS OF THE *Muraenichthys cookei–laticaudata* COMPLEX

Distances are expressed in thousandths of the standard length. Plus values indicate distances of the dorsal origin in front of the anus; minus values, distances behind the anus

SPECIES AND LOCALITY	NUMBER OF SPECIMENS	DISTANCE FROM ANUS	
		Average	Range
Muraenichthys laticaudata			
Marshalls	3	−26	−80 to + 11
Muraenichthys cookei			
Hawaiian Islands			
Midway	7	12	0 to + 23
Oahu	7	20	+ 3 to + 39
Johnston	12	50	+15 to +116

ity is high and the available specimens from any one locality few. First, the two "species" cannot always be separated on the basis of the dorsal origin, for the ranges of the Marshallese and Midway specimens overlap. Second, the Marshallese *M. laticaudata* is most like the Midway form of *M. cookei*, which becomes progressively more distinct at Oahu and Johnston. One would like to know the nature of the populations of this species complex at Wake, a northern outlier of the Marshalls and somewhat between the rest of the group and Midway, but it has never been taken there. One would also like to know about the Line Island populations, but again the species complex is unrecorded from there. In the absence of evidence from these rather crucial localities, one can only speculate that the complex moved into Hawaii from the west, becoming further and further differentiated as it moved down the chain and thence to Johnston. Whatever the derivation, the fact remains that in the habitat (Johnston) that most resembles that of the presumably ancestral *M. laticaudata* the differentiation is the greatest and in the habitat that least resembles the Central Pacific (Midway) the differentiation has been least. Thus the character by which *M. cookei* is distinguished from *M. laticaudata* cannot be explained as an adaptation to a cold-water environment; it would seem rather to be an instance in which differentiation has proceeded independently of the environment.

Gymnothorax eurostus–buroensis

The Hawaiian *Gymnothorax eurostus* is very similar to the Central Pacific species which has been called in recent years *G. buroensis*. Schultz (in Schultz, *et al.*, 1953: 120) has separated the two on the basis of minor color differences. The most important of these is the mottling of the lower jaw in *G. eurostus* as contrasted with the plain throat and lower jaw of *G. buroensis*. Unfortunately, *G. eurostus* at least is very variable in coloration, and almost any color character breaks down in some individuals. The color differentiation of the two species can, however, be supplemented by a number of morphological characters, but for each of these there are, again, individual exceptions. At any given size over perhaps 7 inches, *G. buroensis* is a chunkier fish, and the head especially is higher and blunter, but both species become more heavy-bodied with age. (This and other proportional characters do not seem worth stating quantitatively because of the difficulty of obtaining reliable measurements on morays.) The mouth of *G. buroenis* closes completely; that of *G. eurostus* does not, leaving a gap between the lips just ahead of the eye when the jaw

tips are tightly closed. The length of the snout is usually less than the distance from the eye to the rictus in *G. buroensis*, greater in *G. eurostus*. The fifth pore from the front on the chin is usually behind the most posterior pore on the upper lip and behind the eye in *G. buroensis*, under or in front of the last pore of the upper lip and under the eye in *G. eurostus*. There are fewer teeth in the jaws of *G. buroensis* than of *G. eurostus*, but since adult morays usually lose teeth this character again does not seem to merit quantitative analysis. Finally, *G. buroensis* is definitely the smaller of the two species: the largest of several hundred specimens of *G. buroensis* taken by Schultz in the Marshalls (Schultz, *et al.*, 1953: 118) was about 13 inches; the largest of 20 specimens of *G. eurostus* taken by me in Johnston is 20 inches long. In sum then, the two species are rather easy to separate for anyone familiar with them, even though there is no single character on the basis of which it would be possible to correctly identify all specimens.

Due to the nature of the differences between the two species it can only be stated without adequate demonstration that all specimens of this complex from Johnston are typical *G. eurostus*. Specimens from Christmas, in the Line Islands to the south of Johnston, seem to be typical *G. buroensis*. All of the hundreds of specimens from the Hawaiian Islands seen by me, with one exception, are *G. eurostus*. The exception consists of specimens taken by Mr. Tinker of the Honolulu Aquarium from among the heavy fouling on the bottom of a barge that was put in drydock at Pearl Harbor (see Chapman and Schultz, 1952: 528, Edmondson, 1951: 212). The eel that dropped out of this fouling is a typical specimen of *G. buroensis*. Inasmuch as several other fishes, crustacea, and mollusks taken from this fouling have never been recorded elsewhere in Hawaiian waters, and inasmuch as the barge had been towed in from Guam, it seems logical to presume, despite Chapman and Schultz, that these alien forms came in with the barge from somewhere in the Central Pacific.

Kuhlia sandvicensis–marginata

Despite previous accounts (e.g., Fowler, 1949: 83) there seems to be only one species of *Kuhlia*, namely *K. sandvicensis*, represented in the Hawaiian chain. This species is closely related to *K. marginata* from the Central Pacific, with which it will here be compared. Before doing so it seems well to mention that from published accounts (e.g., Ikeda, 1939: 131–158) *K. boninensis* from the Bonin and Riu Kiu Islands also seems to be near *K. sandvicensis*.

According to Schultz (in Schultz, *et al.*, 1953: 325) *K. marginata* differs from *K. sandvicensis* in having somewhat higher average pectoral and dorsal counts. However, the two species also differ in the number of gill rakers, and it is these that will be emphasized in this analysis.

In the number of dorsal rays, my counts of *K. sandvicensis* agree more closely with Schultz's counts of *K. marginata* than with his data for *K. sandvicensis* (Table 4). Under the circumstances there seems no point in following the analysis of this character further.

The total pectoral ray counts in certain samples of the *K. sandvicensis–marginata* complex are summarized in Table 5. Several aspects of this table warrant discussion. In the

TABLE 4

DORSAL SOFT RAY COUNTS IN THE *Kuhlia sandvicensis–marginata* COMPLEX

SPECIES AND LOCALITY	NUMBER OF SPECIMENS	AVERAGE COUNT
K. sandvicensis		
Hawaiian Islands		
Midway	25	11.08
French Frigate	5	11.00
Kauai	25	11.08
Oahu	25	11.04
Oahu (Schultz)	9	11.55
K. marginata		
Johnston (Schultz)	2	11.00
Marshalls (Schultz)	10	11.00

first place the several small samples available from Midway vary considerably in average count. What this means is not clear, but it has prevented me from placing too much faith in the results of single larger samples from elsewhere. If one were to exclude the samples from the low Hawaiian Islands (Midway, Lisianski, and French Frigate) one would obtain a correlation between increase in pectoral count and decrease in water temperature for the species complex. On the other hand, if one considered the samples of *Kuhlia sandvicensis* alone, one would obtain a correlation in the reverse direction. An attempt to explain these contradictory trends will be made after consideration of the gill-raker data. Meanwhile, it may be noted that the Johnston fishes appear to be of almost pure Central Pacific stock.

Before proceeding with the gill-raker information, three features should be noted. In the first place, as Schultz (1943: 99) has observed, the young of *Kuhlia* have fewer gill rakers than the adult. By plotting the number of gill rakers against standard length in certain large Hawaiian samples, it was determined that *K. sandvicensis* obtains approximately its full gill-raker complement by about 40 millimeters in standard length. Consequently no fish smaller than 40 millimeters were used in the data which follow. The second point regards the method of making counts. In *Kuhlia* the most anterior one of two rakers frequently taper to almost nothing, and it seems preferable to count only the developed gill rakers. Here, then, only the pectinate rakers are counted; the shorter, nob-topped rakers are omitted. Even this restriction leaves some specimens in which the count remains somewhat questionable. To check the consistency in my own counting, the gill rakers in a sample of 37 fish were recounted at the end of a year. The original count gave an average of 24.41, the later count, 24.57. These and all other counts used here are only those below the angle (excluding the raker at the angle).

TABLE 5

TOTAL PECTORAL RAY COUNTS IN SPECIMENS OF THE *Kuhlia sandvicensis–marginata* COMPLEX

SPECIES AND LOCALITY	NUMBER OF SPECIMENS	AVERAGE COUNT
K. sandvicensis		
Hawaiian Islands		
Midway (Mar., 1949)	7	14.57
Midway (July, 1949)	12	14.91
Midway (June, 1950)	6	14.33
Midway (May, 1951)	3	15.00
Midway (all specimens)	28	14.72
Lisianski	3	14.33
French Frigate	5	14.60
Kauai	10	14.80
Oahu	25	14.76
Oahu (Schultz)	17	15.00
Hawaii	22	15.00
K. marginata		
Johnston	9	14.00
Line Is.: Palmyra	2	14.00
Wake	20	14.00
Marshalls (Schultz)	10	13.71

Pectinate gill rakers on the lower limb of the first arch range from 22 to 28 in my samples of *K. sandvicensis*, from 24 to 29 in the smaller numbers of *K. marginata* examined. It seems well to discuss the *K. sandvicensis* samples first, as these are both the largest and the most numerous. In the first place it seems as if those samples containing small fish have somewhat lower average counts than the samples with large fish (Table 6). Perhaps the gill raker number does continue to increase above 40 mm.

With this in mind, the pairs of samples from the same island may be compared. The two Oahu samples were taken in different years from exactly the same tide pool. The difference between the means of these two samples is 0.41. The two samples from Hawaii are of an entirely different sort. One was taken from fresh water, the other from the sea. The difference between the means of these samples is 1.50 gill rakers, though part

of this difference may be attributable to the different sized specimens in the sample. At any rate, it seems from the above data that (presumably) environmental differences within areas may play a considerable role in the differentiation of gill raker counts, and this must be kept in mind in assessing the biological significance of the difference between samples.

Even allowing for this variability within areas, the gill raker counts for *K. sandvicensis* at Midway seem to be considerably higher than for other areas. The increase in Midway counts over those of Pearl and Hermes reef some 90 miles away is especially curious.

Among the samples of *K. marginata* about all that can be said is that the counts for the Johnston and Wake specimens seem to be particularly high. On the other hand the few counts from Penrhyn, about as far south of the equator as Johnston and Wake are north, are low. Any attempt to correlate gill-raker counts with water temperatures in this species complex on the basis of the present material seems fatuous.

Summing up the data for the *Kuhlia sandvicensis–marginata* complex, it may be said that the Johnston and Wake samples show absolutely no indication of introgression from the Hawaiian species so far as gill-raker counts are concerned. Conversely, the samples from the high Hawaiian islands show no sign of intermixing from *K. marginata*. However, the low Hawaiian island samples, particularly those from Midway, show a trend toward the southern form. Since Midway has the water temperatures and total environment least like those of the areas in which *K. marginata* lives, the similarity of the Midway *K. sandvicensis* to *K. marginata* can best be explained by introgression from the latter species. Whether such introgression is brought about through specimens of *K. marginata* coming in from Johnston, Wake, Marcus or elsewhere remains unknown.

TABLE 6

THE NUMBER OF PECTINATE GILL RAKERS ON THE LOWER LIMB OF THE FIRST GILL ARCH IN SAMPLES OF THE *Kuhlia sandvicensis–marginata* COMPLEX

SPECIES AND LOCALITY	NUMBER OF SPECIMENS	AVERAGE COUNT	STANDARD DEVIATION	AVERAGE STANDARD LENGTH IN MM.
K. sandvicensis				
Hawaiian Islands				
Midway (July, 1949)	25	25.40	1.24	61.0
Midway (June, 1950)	29	25.28	0.80	over 100*
Pearl and Hermes	22	24.18	0.73	over 100*
Lisianski	39	24.41	0.75	over 100*
French Frigate	5	24.20		61.8
Kauai	25	24.64	1.25	135.6
Oahu (Waimea, 1948)	37	24.41	0.75	69.6
Oahu (Waimea, 1949)	33	24.82	0.73	62.6
Hawaii (Puna Coast)	22	24.77	0.87	47.0
K. marginata				
Johnston	9	27.33	0.50	180.0
Line Is.: Palmyra	5	26.40		156.6
Phoenix Is.: Canton	3	26.00		198.3
Cook Is.: Penrhyn	6	25.67		71.8
Wake	18	27.20	1.24	121.0
Marcus	5	26.00		84.8

* Large specimens discarded in field.

In view of what has been said above, a hypothetical explanation can be given for the relationship between pectoral counts and sea temperatures. The basic assumption is that pectoral counts in this species complex increase with decreasing temperatures. In partial isolation the Hawaiian island populations would then have developed distinctly higher pectoral counts. These would be higher at Midway at the northern end of the chain than at Hawaii at the southern. However, recent introgression from *K. marginata* at Midway could have upset this trend within the Hawaiian chain, giving rise to the reversed picture for pectoral counts within the Hawaiian Islands shown in Table 5.

The fact remains that there is more difference between the *Kuhlia* populations in Johnston and Hawaii, which are almost similar in latitude, than between those of Johnston and Midway, which are very different. The conclusion seems inescapable that if members of the Johnston populations have entered the Hawaiian Islands at all, they have come in via the low northern islands. Why the Central Pacific form of *Kuhlia* rather than the endemic Hawaiian form should be present at Johnston remains a mystery. It does, however, bear out the point, previously established, that some elements of the Johnston biota have entered from the south.

Cirrhitus alternatus–pinnulatus

The two forms in this complex have recently been differentiated by Schultz (1950: 548), but entirely on the basis of coloration, the Hawaiian *C. alternatus* lacking the brown spotting of the Central Pacific species. A check of the usual meristic characters in specimens from Hawaii, Johnston, and Christmas (in the Line Islands) shows no significant differentiation. As Schultz has already pointed out (*loc. cit.*), the Johnston specimens agree completely with the Hawaiian form.

Chaetodon multicinctus–punctato-fasciatus

This species pair has been separated by Woods (in Schultz, *et al.*, 1953: 571, 575, 595) on the basis of coloration and certain counts. The color differences lie chiefly in the nature of the vertical dark bars on the nape and caudal peduncle. The fin ray differences are shown in Table 7. Woods (*loc. cit.*) has also used scale counts, but I have not been able to make sufficiently accurate scale counts in this species to be worth recording.

The Johnston specimens agree with the Hawaiian form in both color and counts.

Acanthurus sandvicensis–triostegus

The *Acanthurus triostegus* complex lends itself admirably to geographic analysis for two reasons. First, its forms are abundant and ubiquitous throughout much of the tropical Indo-Pacific, and, second, they differ in characteristics that are easily seen and calibrated. A preliminary analysis of geographic variation in this complex has recently appeared (Schultz and Woods, 1948: 248–251). According to these authors two species are represented: *Acanthurus sandvicensis* in the Hawaiian Islands and at Johnston, and *A. triostegus* throughout the rest of the area. The differences between these two lie primarily in the shape and extent of the mark below and at base of the pectoral, secondarily in the higher average fin counts of the Hawaiian species.

The Johnston Island population, judging from 21 specimens taken in three Johnston localities, differs in no way that I can determine from the Hawaiian form. If there is any admixture of *A. triostegus* genes in these Johnston specimens, it is not apparent. If, however, populations of the *A. triostegus* complex from the next island groups to the south of Johnston are examined an occasional specimen turns up with more or less strong traces of the Hawaiian pectoral base marking. For a study of possible intergradation between the Hawaiian *A. sandvicensis* and the Indo-Pacific *A. triostegus* it seems advisable therefore to focus attention not on Johnston but on the Line and Phoenix Islands to the south of Johnston.

TABLE 7

FIN COUNTS IN SPECIMENS OF THE *Chaetodon multicinctus–punctato-fasciatus* COMPLEX

SPECIES AND LOCALITY	DORSAL SOFT RAYS					ANAL SOFT RAYS			PECTORAL*		
	22	23	24	25	26	17	18	19	13	14	15
C. multicinctus											
Hawaiian Islands (Woods)			1	7			3	6		5	4
Honolulu			1	4	1		3	3		3	
Johnston			1	1	1		1	2		3	
C. punctato-fasciatus											
Marshalls (Woods)	1	2	6	1		4	6		2	6	

* Splint at top of pectoral fin not included.

In color pattern three rather distinctive types have been distinguished in the Central Pacific. (1) In the Marshalls (according to Schultz and Woods, *op. cit.*, p. 250, table 1) specimens of *A. triostegus* almost always have a single spot at the upper end of the pectoral fin base. In addition (Schultz and Woods, in Schultz, *et al.*, 1953: 625) the black marking on the caudal peduncle is "represented by a spot on dorsal and ventral sides, or a saddle, sometimes absent except for a small spot on dorsal surface only, never completely across side of caudal peduncle." (2) *Acanthurus sandvicensis* consistently has a dark bar across the pectoral base, which is continued downward and somewhat backward on the body. On the caudal peduncle there is a black saddle which extends one third to one half way down the side of the peduncle; there is no spotting below this saddle. (3) In the Marquesas (according to Schultz and Woods, 1948, *loc. cit.*) *A. triostegus* consistently has two spots at each pectoral base, one at the upper part of the base as in the Marshallese form, and another on the body just below the base. These two spots are connected in the young. The caudal saddle in the Marquesan specimens is usually as in the Marshallese form but, in 6 out of 18 specimens, "extending down sides of caudal peduncle and joining with spot on lower sides" on at least one side of the body (Schultz and Woods, 1948, *loc. cit.*). All of the three color types cited above may be found in specimens from Line and Phoenix Island samples in addition to variants not apparently found elsewhere. Quite frequently markings characteristic of two different races occur on the two sides of the same Phoenix or Line Island fish.

If a stripe running down on to the body below the base of the pectoral fin is designated as A, a single spot on the upper part of the pectoral fin base as B, two spots, one on and one below the fin base as C, and a bar across, and limited to, the fin base as D, Table 8 may be prepared. (The A, B, C, and D types are essentially those similarly designated in Schultz and Woods (1948: 249 and in Schultz, *et al.*, 1953: 625). Actually the four types are not sharply distinct in Phoenix and Line Island fishes. In these areas the A type band extends only slightly below the pectoral base (about as in type E of Schultz and Woods and not well below as in *Acanthurus sandvicensis*) and thus can only be distinguished by definition from D. Furthermore in a few specimens the lower part of the stripe of A tends to become separate and thus grades into C. Finally an elongate spot (B) grades into a bar (D).)

From this table it may be seen that between these two samples all combinations of the different types of pectoral marking may and do occur on opposite sides of the same fish. Indeed, 16 out of 60 specimens have different types of pectoral markings on the two sides of the body. The instability in these populations of the types of pectoral markings that

are elsewhere nearly constant is excessive.

If one considers B to be the pure Marshallese form, C to be the Marquesan, and A and D a tendency toward the Hawaiian species, then the table may be recalculated as is done in Table 9.

Table 9 demonstrates the unity in pectoral markings of the two samples from the northern Line Islands (Christmas) and the southern Phoenix Islands (Hull). These two islands are, incidentally, some 800 air miles from one another. Also, if types B and D really are a tendency towards *A. sandvicensis*, some indication of intergradation with the Hawaiian species seems present in both samples.

Summarizing the data on pectoral markings in the Phoenix–Line populations, it may be said that these contain to some degree all the marking types to be found in the more constant races to the west (Marshallese), north (Hawaiian), and southeast (Marquesan).

In regard to caudal peduncle markings, a similar concentration of variability in the Phoenix and Line Island samples could probably be demonstrated. However, an analysis of the caudal markings suffers from the two facts that the Marshallese and Marquesan races are not particularly constant in this feature and that the Hawaiian marking is to some extent intermediate between the Marquesan and Marshallese pattern. Suffice it, then, to say here that the same bilateral asymmetry in the coloration on the caudal peduncle takes place as occurs in the pectoral marking, that there does not seem to be any correlation between the shape of the marks on the caudal peduncle and those at the pectoral bases, and finally that there are again all gradations between the various types of caudal markings.

The other feature used by Schultz and Woods (*op. cit.*) in separating the forms of the *Acanthurus triostegus* complex is the dorsal, anal, and pectoral fin counts. The Hawaiian species was found to have higher average sample values for each of these fins than samples from elsewhere. Schultz and Woods go on to note that the somewhat lower water temperatures of the Hawaiian area may be responsible for this.

Dorsal, anal, and pectoral counts of certain samples from the Hawaiian, Line, and Phoenix Islands, along with the average annual water temperatures (as calculated from Charts II and III at the back of Sverdrup, Johnston, and Fleming, 1946) are shown in Table 10. Several points about this table need discussion. The first regards variation within areas. Thus, two samples from the single island of Oahu have an average difference of nearly 0.2 of a dorsal ray. Indeed, one suspects that different populations from the same area might differ by perhaps 0.3 dorsal ray, 0.2 anal ray, and 0.1 pectoral ray, though available data is insufficient to prove this. At least nothing less than such amounts should be considered geographically significant. Second, the various island groups investigated seem to have rather different average counts, as summarized in Table 10. The Phoenix (Hull Island) sample, well to the south of the Line Islands and still farther away from Hawaii seems to be intermediate between the Line and Hawaiian Island samples. Another Phoenix Island lot counted by Schultz and Woods (1948: table I) indicates the same thing. Certainly, no genetic intermixing between the Hawaiian and Line Island samples is indicated. If one attempts to explain the change in average count by temperature effect, the Line Island samples create the same stumbling block as for introgression, for temperatures in the Phoenix Islands seem to be higher (and should therefore give lower, not higher, average counts than for the Line Island lots).

Summarizing for the *Acanthurus sandvicensis–triostegus* complex, the following points may be made. There is no sign of intergradation between *A. sandvicensis* and *A. triostegus* at Johnston; the pure Hawaiian form is represented there. In the Line and Phoenix Island samples there is some indication of the *A. sandvicensis* pectoral marking in some speci-

TABLE 8

TYPES OF MARKINGS AT PECTORAL BASE IN PHOENIX AND LINE ISLAND SAMPLES OF *Acanthurus triostegus*
For explanation of lettering, see text

LOCALITY	AA	AB	AC	AD	BB	BC	BD	CC	CD	DD
Line Is.: Christmas	1	0	1	1	15	1	4	3	0	1
Phoenix Is.: Hull	4	2	0	1	17	2	3	2	1	1

TABLE 9

TYPES OF MARKINGS AT PECTORAL BASE IN PHOENIX AND LINE ISLAND SAMPLES OF *Acanthurus triostegus*

LOCALITY	"MARSHALLESE"	"MARQUESAN"	"HAWAIIAN"
Line Is.: Christmas	35 (65%)	8 (15%)	11 (20%)
Phoenix Is.: Hull	41 (52%)	7 (11%)	18 (27%)

mens. That introgression of *A. sandvicensis* genes into these populations has occured via passage of Hawaiian individuals through the Line Islands is contra-indicated by the average fin counts of Line Island samples.

Results of the Species Analyses

Though the nature of the available material precludes very extensive cross comparisons between species, a certain amount of integration between the results of the various species can be made.

The first point regards the nature of the morphological distinctions of the Hawaiian endemic forms. In an earlier paper (Gosline, In press) it was stated: "In morphological features the Hawaiian endemic fishes show no pattern of divergence from their Central Pacific relatives." However, in view of Strasburg's recent paper (1955) demonstrating that in the *Istiblennius edentulus* complex there is a rather close correlation between fin ray count and water temperature, it seems well to reinvestigate this statement. Among the six species pairs dealt with here, four differ in coloration, three in meristic counts, one in the position of the dorsal origin, and one in the shape of the head. Of those differing in color, *Gymnothorax eurostus* is separable primarily on the basis of the mottling of the throat, *Cirrhitus alternatus* in the absence of brown spots on the body, *Chaetodon multicinctus* in the presence of more prominent barring on the nape and caudal peduncle, and *Acanthurus sandvicensis* in the long curved streak below the pectoral base. There seems to be no pattern of differentiation here. However, a pattern does emerge from the meristic data. Of those species pairs differing in meristic characters, two of the Hawaiian endemics have more pectoral rays (*Kuhlia sandvicensis* and *Chaetodon multicinctus*), two have more dorsal and anal soft rays (*Chaetodon multicinctus* and *Acanthurus sandvicensis*), and one has *fewer* gill rakers (*Kuhlia sandvicensis*). Thus for fin rays, if not for gill rakers, there does seem to be a trend toward higher meristic counts in these Hawaiian endemics. Other species showing the same trend that are not dealt with here are *Istiblennius zebra* (see Strasburg, *op. cit.*) and *Dascyllus albisella*. However, what has just been said should not obscure the fact that there are many species in which the Hawaiian form shows no increase in counts and at least a few in which a decrease occurs. Thus the Hawaiian trichonotid *Crystallodytes cookei* differs from its Phoenix Island counterpart only, so far as known, in having *fewer* dorsal and anal rays (Schultz, 1943: 266), and the Hawaiian gobioid *Kraemeria bryani* differs

TABLE 10

FIN COUNTS FOR CERTAIN SAMPLES OF THE *Acanthurus sandvicensis–triostegus* COMPLEX

For the counts averages are given above and standard deviations below in parentheses. No standard deviations were calculated for the counts drawn from Schultz and Woods (1948: table 1) as these appear to represent combined samples

LOCALITY	AVERAGE ANNUAL SURFACE WATER TEMPERATURE	NUMBER OF SPECIMENS	SOFT DORSAL RAYS	SOFT ANAL RAYS	TOTAL PECTORAL RAYS
Hawaii: Midway	22.0° C	18	23.33 (±.57)	20.67 (±.57)	15.89 (±.33)
Hawaii: Oahu (tide pool on exposed NW coast)	24.5	20	23.45 (±.55)	20.75 (±.58)	15.85 (±.36)
Hawaii: Oahu (reef-enclosed bay)	24.5	46	23.28 (±.62)	20.67 (±.47)	15.83 (±.38)
Hawaii and Johnston (from Schultz and Woods)		32	23.59	20.84	15.84
Johnston	26.0	21	23.47 (±.60)	20.67 (±.80)	15.81 (±.40)
Line: Palmyra	26.8	36	22.78 (±.59)	19.58 (±.92)	15.50 (±.50)
Line: Christmas	26.1	26	22.46 (±.51)	19.46 (±.58)	15.46 (±.51)
Phoenix: Hull	27.3	33	23.03 (±.52)	20.00 (±.49)	15.45 (±.50)
Phoenix (from Schultz and Woods)		11	23.09	20.36	15.37*
Guam, Marshalls (from Schultz and Woods)		21	22.81	20.14	15.19

* Based on 16 specimens.

from its tropical relative *K. samoensis* most significantly in the *lower* number of pectoral rays (Schultz, 1943: 262).

Zoogeographically there are few definite conclusions that can be drawn from the species analysis, though there are several indications. One of the species, *Kuhlia marginata*, has obviously come to Johnston from the south; the other five have come down from the north. The southern *Kuhlia* shows distinct signs of having introgressed into the northwestern Hawaiian Island populations of *K. sandvicensis*, though whether this has been due to immigration from Johnston or elsewhere remains unknown. Since, however, the prevailing current system around Johnston is from east to west, and even northwest, it seems probable that any migration from Johnston would reach the western leeward Hawaiian Islands rather than the eastern windward islands. Because of this same current system, any Hawaiian fishes arriving at Johnston would probably have come in from the eastern rather than the western islands, and this is what appears to have happened with *Muraenichthys cookei*, judging from the data presented on that species. That Hawaiian endemics, such as *M. cookei*, have gotten from the Hawaiian Islands to Johnston seems certain. That Johnston fishes actually ever got to Hawaii remains unproven.

ZOOGEOGRAPHIC CONCLUSIONS

Although it may be repetitious, it seems well to draw together the results of the second half of this paper for the sake of those who got lost among the pectoral markings of *Acanthurus* or elsewhere.

The Johnston fish fauna is made up of four components (Fig. 4): endemics; fishes that have made Johnston a stopping point on their migrations from the south; fishes that have found Johnston as a way point in their southward travels; and pelagic fishes to whom Johnston is of little or no significance. The last category, which undoubtedly merges into the second and third, has been excluded from consideration in the present paper. The first is made up of only two species which may simply have been as yet unrecorded elsewhere; in any case, there is very little endemism at Johnston. Species that must have come in from the south, since they are as yet unrecorded in Hawaii and those known to have come in from the north, the "Hawaiian endemics," are represented in Johnston in about equal number. In terms of percentages, however, the proportion of the Hawaiian endemic fauna that reached Johnston is far higher than the proportion of the Central Pacific fauna that reached Johnston but not Hawaii. For this reason it is preferable to consider Johnston as an outlier of the Hawaiian faunal area rather than as a peripheral component of the Central Pacific faunal area.

There is no known intergradation between Hawaiian endemics and their Central Pacific counterparts at Johnston. If the Central Pacific form is represented at Johnston it is there in its pure form and the Hawaiian counterpart is absent, and vice versa.

Since many "Hawaiian endemics" are present at Johnston, it is certain that some species at least have traveled from Hawaii to Johnston. It is, however, not proven that any Johnston fishes ever got to Hawaii; nor is it proven that they did not. Consequently, the role that Johnston may have played in the development of the Hawaiian fish fauna remains in doubt. If, however, one rejects Johnston as the stepping stone by means of which the Hawaiian fishes arrived, then one is driven back on immigration routes that, at the present time, are at least equally implausible and unproven.

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NEWS NOTES

Island Bibliographies — A Review

Island Bibliographies, compiled by Marie-Hélène Sachet and Dr. F. Raymond Fosberg and published by the Pacific Science Board, National Academy of Sciences, National Research Council (Publication 335, 577 pages, 1955 [$6.00]), is an outstanding guide to the written knowledge of botany in the Pacific and of the land ecology of atolls throughout the world.

This thick book, produced by offset from typewritten pages, presents the results of three separate bibliographic projects which these careful and energetic authors have carried out for the Pacific Science Board. Each is complete in itself.

Each bibliography lists publications by authors in alphabetical sequence and chronologically under each author. For each there is a concise statement as to its major contents, and for rare publications, a note as to the library and call number where consulted. Each bibliography is followed by a subject index or guide, listing the authors and dates of pertinent articles under subject headings.

The first of the three is an "Annotated bibliography of Micronesian botany," covering the Mariana, Caroline, Marshall and Gilbert archipelagoes, together with a few isolated islands, such as Marcus, Wake, Mapia, Nauru and Ocean, lying adjacent to them.

The second part, "Bibliography of the land ecology and environment of coral atolls," resulted from two symposia on atolls, held in Washington, D.C. and Honolulu in 1951, at which the importance of a survey of what had been written about atolls was stressed. The list of authors and titles covers 183 pages, without its supplement, and the index is 75 pages. The main subject headings of this part include: Geography, Geology, Climate, Effects of hurricanes and typhoons, Water supply, Soils and substratum, Vegetation, Flora, Phytogeography, Fauna, Zoogeography, Economic plants and animals, Ecology, Atolls in general, and groupings of the more than 400 atolls by areas — Pacific, East Indies and China Sea, Indian Ocean, and Caribbean, with extensive subdivision; Expeditions and voyages, Bibliography, Photographs and other illustrations, Maps and charts.

The third part is a "Selected bibliography of vegetation of the tropical Pacific islands." The emphasis is on vegetation, but the listings should be of interest to students of geography, geology, ecology, zoology, climatology, soil science, forestry, agriculture, economics, military science, and engineering. All islands and island groups in the tropical and subtropical Pacific are covered, even those already included in the first of the three bibliographies. The authors state that, "since the amount of information available on different islands and island groups varies exceedingly, the treatment has correspondingly varied. For islands whose vegetation is relatively well-known, fewer obscure and unimportant articles are included, especially where there have been adequate summaries. . . . On the other hand, so little is available on some islands that tiny scraps of information and some of dubious value are listed." No attempt has been made to list floras and check-lists, unless these contain descriptive information on vegetation. Floras are listed by Black and Atwood (U.S. Department of Agriculture Miscellaneous Publication 401, 1942) and by Merrill in his various Pacific botanical bibliographies. The index is entirely geographical, by island groups and many individual islands.

For the sake of conserving space, titles of series publications have been abbreviated. The full title of each serial is listed, together with the place of publication and the name of the library where files are known to exist.

There is an addendum for each of the three bibliographies and the list of serials. The publication includes all items located up to November 1, 1954.

Knowledge of what has been recorded is essential to careful research. This volume is commended to all persons interested in atolls and in the vegetation of tropical Pacific islands.

E. H. Bryan, Jr.

Volume 2 of *Insects of Micronesia,* the *Bibliography* has been issued. This very complete bibliography, with its accompanying index by families and higher categories, will be useful to anyone interested in the terrestrial arthropods of any portion of the Pacific area. The various numbers of the taxonomic volumes have begun to appear and are available by purchase from the Bernice P. Bishop Museum, Honolulu. The price of the *Bibliography* is $2.00, the price of the parts will vary.

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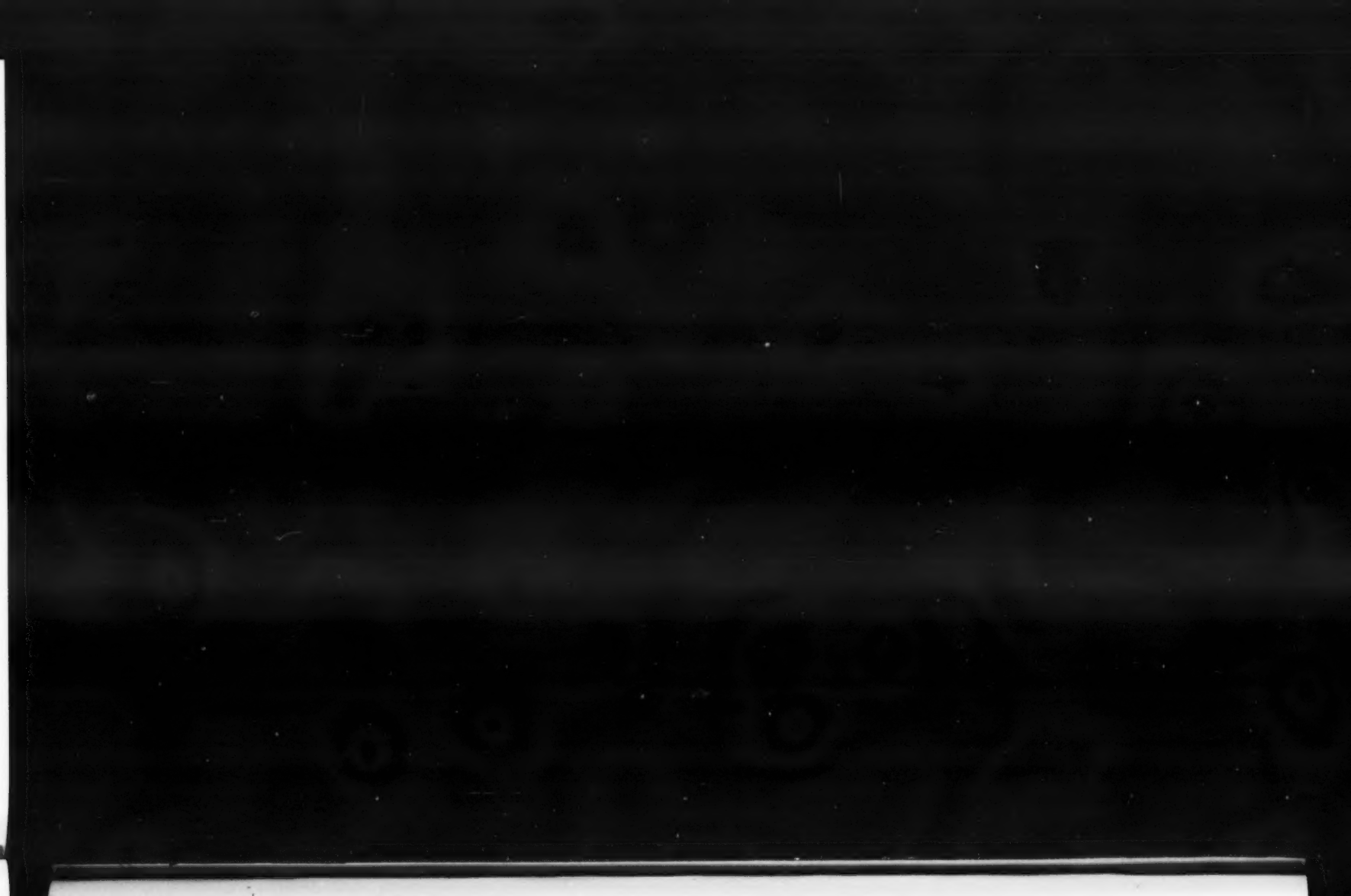
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